

APDIO

ASSOCIAÇÃO PORTUGUESA
DE INVESTIGAÇÃO OPERACIONAL

XXI CONGRESSO
Figueira da Foz
7 a 8 de novembro | 2021

io 2021

ANALYTICS FOR A —
— BETTER WORLD

LIVRO DE RESUMOS

Editado por

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XXI Congresso da Associação Portuguesa de Investigação Operacional

Livro de Resumos

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7 e 8 de novembro 2021

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Mensagem do Presidente da Direção da APDIO

"E se fizéssemos o Congresso num hotel?..."

Foram estas palavras que no início de abril, ainda o país estava sob um regime de mobilidade limitada, desbloquearam a realidade que hoje estamos a viver: o Congresso da APDIO à IO 2021. A Direção da APDIO queria promover um encontro da comunidade de Investigação Operacional, que sentia como desejado e necessário. Mas, apesar da esperança que o processo de vacinação nos trazia, os tempos ainda eram de elevada incerteza, os estabelecimentos de ensino superior estavam a funcionar em modo remoto, e as limitações aos eventos eram numerosas e fortes. A solução segura para o nosso congresso seria o modo online, e chegamos a planear um congresso online espalhado no tempo, mas estávamos todos saturados de Zoom. Queríamos fazê-lo em modo presencial. Tudo nos empurrava para adiar a decisão, mas um congresso requer a realização de preparativos com bastante antecedência. Mas como, quando nenhuma instituição de ensino superior nos cederia instalações?

"E se fizéssemos o Congresso num hotel?... Como o INFORMS faz."

De repente, muitos impossíveis passaram a estar ao alcance das nossas decisões. A escolha de uma data de Outono, época baixa hoteleira, baixava os custos do evento. Decorrendo o congresso num hotel poderíamos ter todos os participantes alojados no mesmo local, maximizando a interação e a partilha. Um local na zona centro do país facilitaria as deslocações. Mas um congresso em pleno semestre letivo não poderia ser longo. Então faziamo-lo ao longo de apenas dois dias, o primeiro dos quais um domingo. E assim, passo a passo chegámos ao IO 2021, no Hotel Eurostars Oasis Plaza, 7 e 8 de novembro.

Mas um problema neste formato de congresso parecia intransponível: não dispondo de salas para sessões paralelas, pelos custos incomportáveis que acarretariam, como ter as habituais dezenas de apresentações em apenas um dia e meio? Transformando dificuldades em oportunidades, lançou-se a ideia de todas as apresentações serem sob a forma de poster, promovendo e treinando competências de comunicação científica, com o envolvimento dos próprios participantes na votação de quais os posters que seriam alvo de uma curta apresentação, seguida de discussão. Pecha Kucha, timer, sistemas de votação, formatos, A1, A0, A2, foram termos e palavras que voaram pelos ares até se chegar ao modelo de congresso que hoje vamos tornar vivo. A adesão da comunidade de Investigação Operacional, com mais de 80 posters submetidos e cerca de 130 participantes no congresso, foi extraordinária e faz-nos acreditar que a aposta foi ganha.

Como é habitual nos congressos, procurámos um tema. Mas o momento histórico que vivíamos tornava óbvia a escolha: "Analytics for a Better World". E aqui temos que agradecer vivamente aos nossos palestrantes convidados. O colega Manuel Matos irá falar-nos da incerteza nos processos de decisão. Sabemos que a incerteza é mais a regra do que exceção, mas tem especial impacto quando vidas humanas estão em jogo, em aplicações de logística humanitária, ou na gestão de desastres. E este é o dia a dia do Eng. Sérgio Guedes Silva, que lidera a equipa de gestão da cadeia de abastecimento da World Food Program (WFP), a partir do quartel-general da WFP em Roma, e que nos falará sobre "The power of analytics in a Humanitarian Context". Missão igualmente sensível foi a que o Sr. Vice-Almirante Gouveia e Melo assumiu, ao liderar a task-force que em Portugal geriu o processo de vacinação contra a COVID-19. Para bem de Portugal, o sucesso do seu trabalho foi avassalador. Queremos acreditar que o facto de ter sido a Marinha de Portugal a introduzir em Portugal o ensino da Investigação Operacional, há mais de 50 anos, não tenha sido alheio a este sucesso. Por isso, quisemos ouvir do Sr. Vice-Almirante os principais desafios enfrentados e as lições aprendidas neste processo. A pandemia teve impactos inesperados em vários setores da economia, mas a logística é uma das atividades que ainda hoje está mais afetada e sem solução à vista para a disrupção sofrida. A gestão das cadeias de abastecimento é a área de trabalho do Pedro Amorim, e é a partir desta aplicação que irá refletir sobre como podemos alavancar a relevância prática da nossa investigação em Investigação Operacional. Mais uma vez, estamos muito gratos aos quatro palestrantes por terem aceitado o nosso convite e é com muito interesse que os iremos ouvir.

Acredito que a complexidade e incerteza associada à organização deste congresso terão ficado claras nas minhas palavras anteriores. Por isso mesmo, a Direção da APDIO não podia pedir a ninguém para organizar o congresso, tinha que o fazer ela própria. Foi assim que assumimos o papel de Comissão Organizadora. Foi assim que se passaram faturas, se geriram recebimentos, se fez o site e geriu toda

a comunicação, se prepararam templates e se fez o livro de resumos, se arrendaram salas, contrataram refeições e se construiu um programa social. Enfim, tudo o que é habitual numa conferência foi tratado pela Cristina, pela Carla, pela Maria Antónia e pela Ana, superiormente coordenados pelo incansável Samuel, a quem todos devemos uma salva de palmas: ele foi a alma e o músculo desta organização. Obrigado a todos.

Finalmente, um agradecimento muito profundo a todos os colegas da Comissão de Programa (que terão ainda a tarefa de rever os artigos que serão publicados no livro do congresso, editado pela Springer), e das comissões dos vários prémios que teremos este ano. A vossa colaboração foi fundamental para o sucesso deste modelo de congresso.

Caros sócios da APDIO. Este é o último congresso em que me dirijo a vós, enquanto Presidente da Direção da APDIO. Por isso, gostava de deixar uma palavra de agradecimento por terem confiado em mim para conduzir os destinos da associação durante 6 anos. A quem me venha a suceder só posso dizer uma coisa: Não se preocupem! Dirigir uma associação com pessoas com a qualidade, a dedicação, o entusiasmo e o empenho que os sócios da APDIO têm, é muito fácil.

E agora, vamos começar o congresso!

Figueira da Foz, 7 de novembro de 2021

José Fernando Oliveira
Presidente da Direção da APDIO

Nota do Presidente da Comissão de Programa

É com enorme satisfação que recebemos a vossa participação no maior evento nacional de Investigação Operacional. Com mais de 120 participantes inscritos e cerca de 80 trabalhos submetidos, o IO2021 vem dar assim continuidade à nossa importante missão de comunicar, divulgar e abordar problemas complexos que impactam a nossa sociedade, economia e ambiente. Apesar da investigação de excelência que tem vindo a ser desenvolvida, os problemas maiores continuam por resolver e, por isso, quisemos com o IO2021 desafiar a nossa comunidade a apresentar modelos, metodologias e novas perspetivas de análise que indiquem caminhos para um mundo melhor.

Tempos diferentes exigem abordagens diferentes. Reinventamos o Congresso da APDIO, num programa mais concentrado que visa inspirar os mais novos e seja facilitador de produção de conhecimento entre pares. Teremos um dia e meio de congresso com apresentações plenárias e mesas redondas, que se realizarão sempre no mesmo espaço. O dia de domingo será reservado a dois oradores destacados, o Vice-Almirante Gouveia e Melo e o Eng. Sérgio Guedes Silva, e à discussão e votação dos posters. Nas plenárias de segunda-feira, teremos os Professores Manuel Matos e Pedro Amorim, e um total de 25 apresentações de trabalhos num formato de mesas redondas. Um agradecimento muito especial aos oradores convidados pela disponibilidade e contributo. Publicamos ainda o Livro de Resumos dedicados ao XXI Congresso da Associação Portuguesa de Investigação Operacional. Pós-congresso, os artigos aceites no processo de revisão serão publicados nos Springer Proceedings in Mathematics Statistics.

Gostaria de deixar uma palavra de apreço a todos os elementos da Comissão Organizadora, Isabel Cristina Lopes, Carla Geraldês, Maria Antónia Carravilla, Ana Paula Barbosa Póvoa e José Fernando Oliveira, pelo espírito de equipa inabalável que permitiu superar os desafios da conjuntura atual. Saliento, também, o apoio do Departamento de Engenharia Mecânica da Faculdade de Ciências e Tecnologia da Universidade de Coimbra.

Desejamos que o programa científico e social vá de encontro às melhores expectativas e que o IO2021 seja um evento marcante na nossa comunidade.

Figueira da Foz, 7 de novembro de 2021

Samuel Moniz

Presidente da Comissão de Programa

Comissão Organizadora

Samuel Moniz, Universidade de Coimbra (Presidente)

Isabel Cristina Lopes, Instituto Politécnico do Porto

Carla Soares Geraldes, Instituto Politécnico de Bragança

Maria Antónia Carravilla, Faculdade de Engenharia da Universidade do Porto

Ana Paula Barbosa-Póvoa, Instituto Superior Técnico, Universidade de Lisboa

José Fernando Oliveira, Faculdade de Engenharia da Universidade do Porto

Comissão de Programa

Samuel Moniz, Universidade de Coimbra (Presidente)

Agostinho Agra, Universidade de Aveiro Departamento de Matemática

Ana Cristina Amaro, Instituto Politécnico de Coimbra ISCAC | Coimbra Business School

Beatriz Oliveira, Universidade do Porto Faculdade de Engenharia

Carla Soares Gerales, Instituto Politécnico de Bragança

Cláudio Alves, Universidade do Minho Escola de Engenharia

Cristóvão Silva, Universidade de Coimbra

Eliana Costa e Silva, Instituto Politécnico do Porto Escola Superior de Tecnologia e Gestão

Filipe Alvelos, Universidade do Minho Escola de Engenharia

Gonçalo Figueira, Universidade do Porto Faculdade de Engenharia

Isabel Cristina Lopes, Instituto Politécnico do Porto Instituto Superior de Contabilidade e Administração

Isabel Gomes, Universidade Nova de Lisboa Faculdade de Ciências e Tecnologia

João Patrício, Instituto Politécnico de Tomar Escola Superior de Tecnologia de Tomar

João Paulo Almeida, Instituto Politécnico de Bragança

Lia Oliveira, Instituto Politécnico de Viana do Castelo Escola Superior de Ciências Empresariais

Maria Cândida Mourão, Universidade de Lisboa Instituto Superior de Economia e Gestão

Maria Eugénia Captivo, Universidade de Lisboa Faculdade de Ciências

Maria João Alves, Universidade de Coimbra Faculdade de Economia

Miguel Vieira, Universidade Lusófona

Rui Borges, Universidade de Aveiro

Sofia Miranda, NPS Alumni, US Naval Postgraduate School

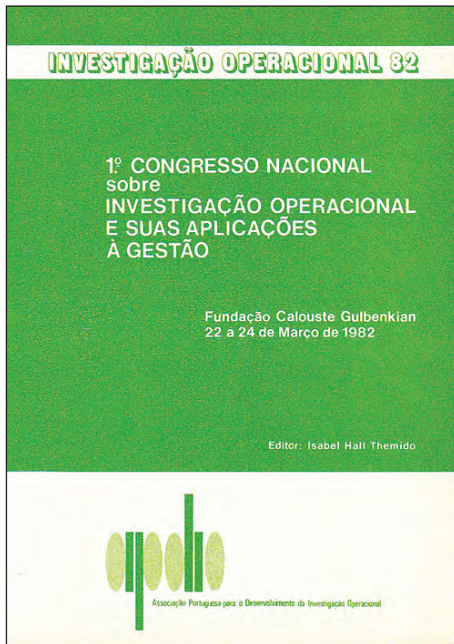
Susana Relvas, Universidade de Lisboa Instituto Superior Técnico

Tânia Ramos, Universidade de Lisboa Instituto Superior Técnico

Telmo Pinto, Universidade de Coimbra

Teresa Cardoso Grilo, Instituto Universitário de Lisboa ISCTE Business School

Edições Anteriores



1º Congresso da APDIO

Lisboa, 22 a 24 de março de 1982
 Fundação Calouste Gulbenkian
 Presidente da Comissão Organizadora
 Aníbal Durães Santos



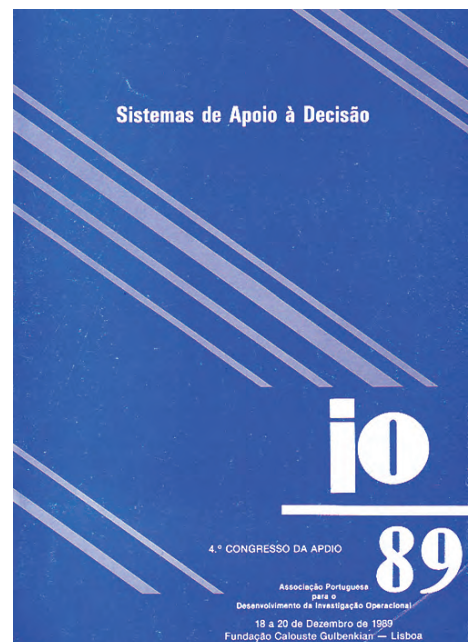
2º Congresso da APDIO

Porto, 16 a 18 de abril de 1984
 Faculdade de Economia da Universidade do Porto
 Presidente da Comissão Organizadora
 Rui Guimarães



3º Congresso da APDIO

Coimbra, 11 a 14 de outubro de 1987
 Universidade de Coimbra
 Presidente da Comissão Organizadora
 Mário da Silva Rosa



4º Congresso da APDIO

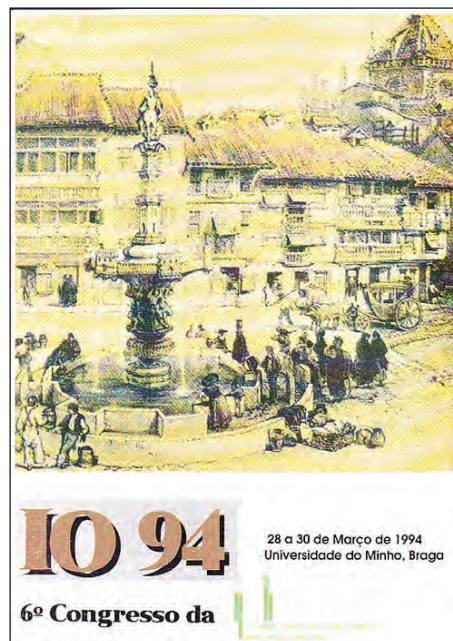
Lisboa, 18 a 20 de dezembro de 1989
 Fundação Calouste Gulbenkian
 Presidente da Comissão Organizadora
 A. J. Simões Monteiro



5º Congresso da APDIO

Évora, 13 a 15 de abril de 1992
Universidade de Évora

Presidente da Comissão de Programa
José Rodrigues Dias
Presidente da Comissão Organizadora
Rui Guimarães



6º Congresso da APDIO

Braga, 28 a 30 de março de 1994
Universidade do Minho

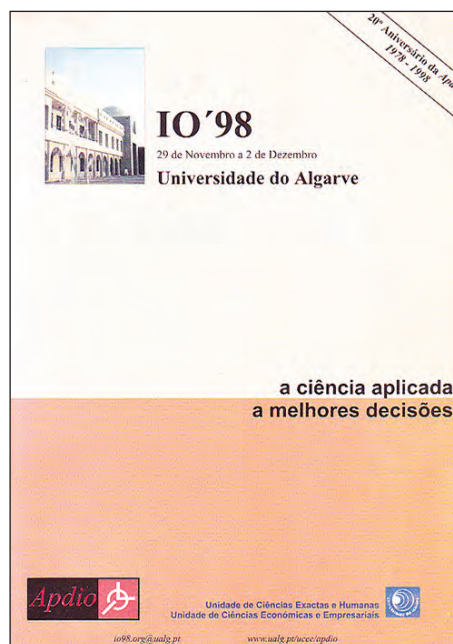
Presidente da Comissão de Programa
Jorge Pinho de Sousa
Presidente da Comissão Organizadora
A. Guimarães Rodrigues



7º Congresso da APDIO

Aveiro, 1 a 3 de abril de 1996
Universidade de Aveiro

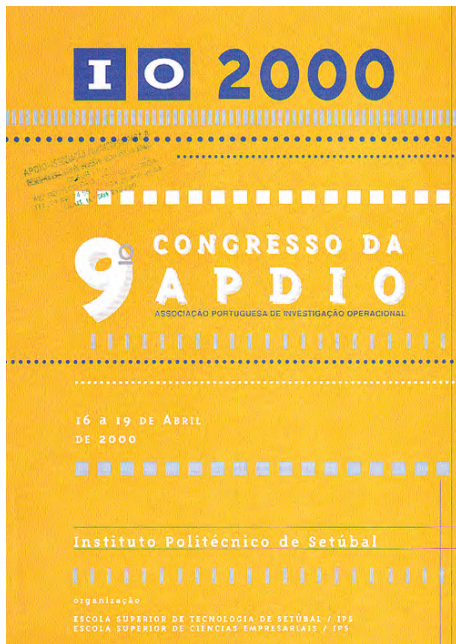
Presidente da Comissão de Programa
Carlos Bana e Costa
Presidente da Comissão Organizadora
Domingos Moreira Cardoso



8º Congresso da APDIO

Faro, 29 de novembro a 2 de dezembro de 1998
Universidade do Algarve

Presidente da Comissão de Programa
José Pinto Paixão
Presidente da Comissão Organizadora
Fernanda Marília Pires



9º Congresso da APDIO

Setúbal, 16 a 19 de abril de 2000
Instituto Politécnico de Setúbal

Presidente da Comissão de Programa
Carlos Henggeler Antunes

Presidente da Comissão Organizadora
Carlos Luz



10º Congresso da APDIO

Guimarães, 24 a 27 de março de 2002
Universidade do Minho

Presidente da Comissão de Programa
José Fernando Oliveira

Presidente da Comissão Organizadora
José Valério de Carvalho



11º Congresso da APDIO

Porto, 4 a 7 de abril de 2004
Faculdade de Engenharia da Universidade do Porto

Presidente da Comissão de Programa
Joaquim João Júdice

Presidente da Comissão Organizadora
Rui Guimarães

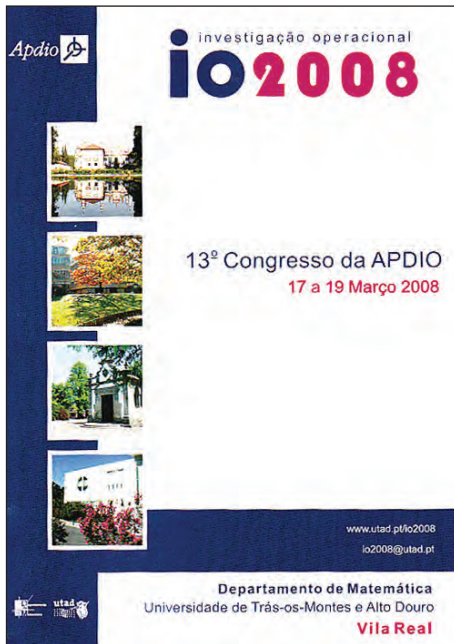


12º Congresso da APDIO

Lisboa, 8 a 11 de outubro de 2006
ISEG - Universidade Técnica de Lisboa

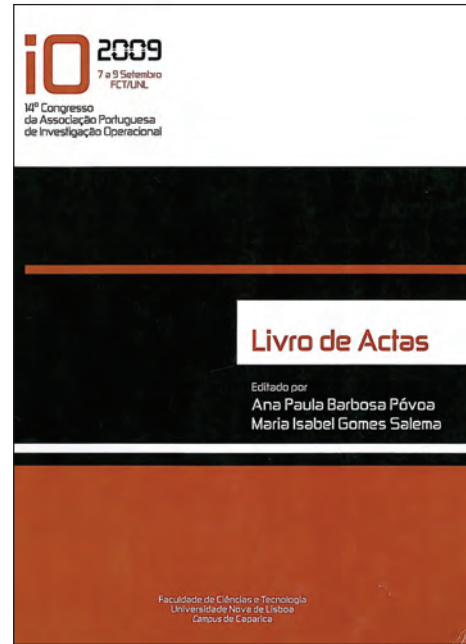
Presidente da Comissão de Programa
Pedro Oliveira

Presidente da Comissão Organizadora
Margarida Vaz Pato



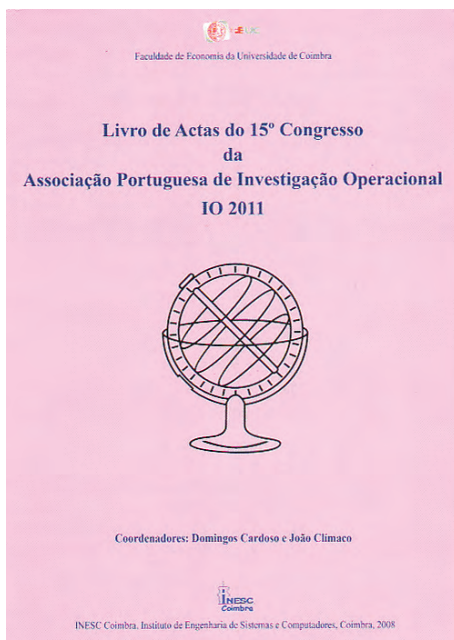
13º Congresso da APDIO

Vila Real, 17 a 19 de março de 2008
 Universidade de Trás os Montes e Alto Douro
 Presidente da Comissão de Programa
 Maria Eugénia Captivo
 Presidente da Comissão Organizadora
 Ana Paula Teixeira



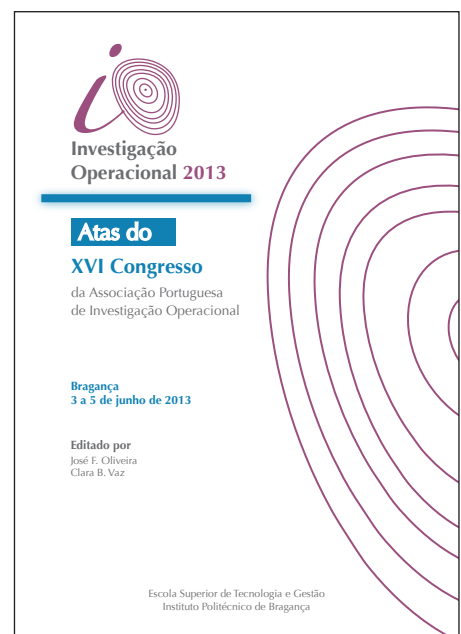
14º Congresso da APDIO

Caparica, 7 a 9 de setembro de 2009
 FCT - Universidade Nova de Lisboa
 Presidente da Comissão de Programa
 Ana Barbosa Póvoa
 Presidente da Comissão Organizadora
 Ruy Costa



15º Congresso da APDIO

Coimbra, 18 a 20 de abril de 2011
 Universidade de Coimbra
 Presidente da Comissão de Programa
 Domingos Moreira Cardoso
 Presidente da Comissão Organizadora
 João Clímaco



16º Congresso da APDIO

Bragança, 3 a 5 de junho de 2013
 Instituto Politécnico de Bragança
 Presidente da Comissão de Programa
 José Fernando Oliveira
 Presidente da Comissão Organizadora
 Clara Bento Vaz

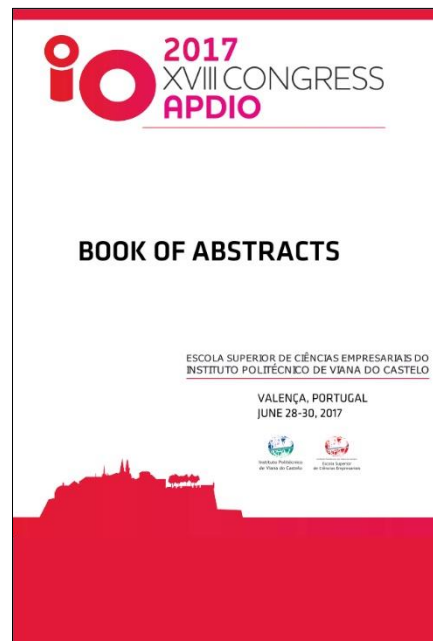


17º Congresso da APDIO

Portalegre, 7 a 9 de setembro de 2015
Instituto Politécnico de Portalegre

Presidente da Comissão de Programa
Ana Paula Barbosa-Póvoa

Presidente da Comissão Organizadora
João Luís de Miranda



18º Congresso da APDIO

Valença, 28 a 30 de junho de 2017
Instituto Politécnico de Viana do Castelo

Presidente da Comissão de Programa
António Ismael Freitas Vaz

Presidente da Comissão Organizadora
Lia Oliveira



19º Congresso da APDIO

Aveiro, 5 a 7 de setembro de 2018
Universidade de Aveiro

Presidente da Comissão de Programa
Maria João Alves

Presidentes da Comissão Organizadora
Ana Raquel Xambre
Helena Alvelos



20º Congresso da APDIO

Tomar, 22 a 24 de julho de 2019
Instituto Politécnico de Tomar

Presidente da Comissão de Programa
Susana Relvas

Presidente da Comissão Organizadora
João Patrício

Programa Geral

Time	November 7 th	Time	November 8 th
15:00	Hotel check-in & get together	07:30	Breakfast
16:00	Welcome drink & poster discussion and voting	08:30	Plenary session Manuel Matos
17:00	Opening remarks & Plenary session Vice-Almirante Gouveia e Melo	09:15	Round table 1
17:45	Coffee break & poster discussion and voting	10:15	Coffee break & poster discussion
18:30	Plenary session Sérgio Guedes Silva	11:00	Round table 2
19:15	Walking to the dinner	12:00	Hotel check-out
20:00	Cocktail and Conference dinner	12:30	Lunch
		14:00	Round table 3
		15:00	Plenary session Pedro Amorim
		15:45	Round table 4
		16:45	Coffee break & poster discussion
		17:30	Round table 5
		18:30	Awards & closing remarks

Sessões Plenárias

Sessão Plenária I

A operação logística da vacinação contra a COVID-19 em Portugal

Vice-Almirante Henrique Gouveia e Melo
Estado-Maior-General das Forças Armadas

Biografia

O Vice-Almirante Henrique Eduardo Passaláqua de Gouveia e Melo nasceu em Quelimane, Moçambique, a 21 de novembro de 1960, e viveu a sua infância e adolescência entre Quelimane, em Moçambique, a cidade de São Paulo, São Paulo, no Brasil e, finalmente, Lisboa, onde chegou aos 18 anos, em setembro de 1979 para ingressar na Escola Naval como Cadete do curso "Carvalho Araújo". Em setembro de 1984, após terminar o curso na Classe de Marinha, com 23 anos, foi promovido a Guarda-Marinha.

Fez o estágio de embarque, de seis meses, na fragata NRP Roberto Ivens, em 1984, antes de assumir as funções de Oficial Imediato do NRP Save, durante um ano, de 1984 a 1985.

Integrou, voluntariamente, a Esquadilha de Submarinos aos 24 anos, em setembro de 1985, onde navegou nos submarinos NRP Albacora, NRP Barracuda e NRP Delfim, tendo nos primeiros anos e até 1992, exercido diversas funções operacionais como oficial de guarnição e posteriormente como Oficial Imediato nos submarinos NRP Albacora e NRP Barracuda. Durante a sua longa permanência na Esquadilha de Submarinos que, nesta fase, terminaria em 2002, teve ainda a oportunidade de comandar os submarinos NRP Delfim e NRP Barracuda, chefiar o Serviço de Treino e Avaliação da Esquadilha de Submarinos e o Estado-Maior da Autoridade Nacional para o Controlo de Operações de Submarinos (SUBOPAUTH).

Após uma passagem de 3 anos como Relações Públicas e Porta-Voz da Marinha, e uma participação decisiva no projeto da nova classe de submarinos, veio a comandar, entre 2006 e 2008, a fragata NRP Vasco da Gama (F330).

Findo este comando no mar, o Almirante Gouveia e Melo retornou ao meio que encerra a sua grande paixão, a Esquadilha de Submarinos, novamente como seu Comandante, para liderar o ambicioso projeto de transformação e reconstrução desta estrutura, capacitando-a para a receção e apoio aos novos submarinos. Foi nesta fase, por falecimento do Comandante do submarino NRP Tridente, que voltou a embarcar como responsável pelas provas, testes e operações durante o primeiro ano de vida desta nova unidade, período de garantia após a receção do navio em Portugal. Antes da promoção a Oficial General foi, ainda, 2.º Comandante da Flotilha de Navios, Diretor de Faróis e Diretor do Instituto de Socorros a Náufragos.

Ao longo da sua carreira, frequentou vários cursos, dos quais se destacam a especialização em Comunicações e Guerra Eletrónica, o "International Diesel Electric Submarine Tracking Course" em Norfolk, Virgínia, nos Estados Unidos da América, o Curso Geral Naval de Guerra, uma Pós-Graduação em "Information Warfare" na Universidade Independente, o Curso Complementar Naval de Guerra e finalmente o Curso de Promoção a Oficial General no Instituto de Estudos Superiores Militares.

Após a promoção a Contra-Almirante, em abril de 2014, foi Chefe de Gabinete do Almirante Chefe do Estado-Maior da Armada até novembro de 2016 e, durante um breve período, o 2.º Comandante Naval, exercendo em suplência as funções de Comandante Naval, até janeiro de 2017. Nessa data, com a promoção a Vice-Almirante, passou a exercer as funções de Comandante Naval, período durante o qual exerceu, em acumulação, as funções de Comandante da Força Naval EUROMARFOR, que integra meios portugueses, espanhóis, franceses e italianos.

É, desde janeiro de 2020, o Adjunto para o Planeamento e Coordenação do Estado-Maior General das Forças Armadas, função que, entre 3 de fevereiro e 28 de setembro de 2021, passou a acumular com as de Coordenador da Task Force para combate à COVID-19.

O Vice-Almirante Gouveia e Melo para além dos submarinos e do mar é um apaixonado pelo mundo das Matemáticas, da Física e da Computação.

Ao longo da sua carreira já foi, também, distinguido com diversas condecorações: Comendador (3 de Junho de 2004) e Grã-Cruz (20 de Agosto de 2021) da Ordem Militar de São Bento de Avis,[4] três Medalhas Militares de Ouro de Serviços Distintos, cinco Medalhas Militares de Prata de Serviços Distintos, Medalha de 1.ª Classe de Mérito Militar, Medalha de 2.ª Classe de Mérito Militar, Medalha de 3.ª Classe de Mérito Militar, Medalha de 1.ª Classe da Defesa Nacional, Medalha de 1.ª Classe da Cruz de São Jorge, Medalha de 3.ª Classe da Cruz Naval, Medalha Militar de Ouro de Comportamento Exemplar, Grande-Oficial da Ordem do Mérito Naval do

Brasil, Medalha Mérito Tamandaré do Brasil, Comendador da Ordem do Mérito Marítimo de França, Medalha de Participação na Operação Sharp Guard.

Sessão Plenária II

The power of analytics in a Humanitarian Context

Sérgio Guedes Silva

World Food Program, Roma

Nearly 690 million people regularly go to bed hungry. This means one in eleven people do not have access to enough food, a situation exacerbated further by the ongoing COVID-19 pandemic. One of the key players addressing this issue is the United Nations World Food Programme (WFP), the world's largest humanitarian organization fighting hunger worldwide and winner of the 2020 Nobel Peace Prize. Just last year, WFP assisted 115.5 million people in 84 countries.

Humanitarian operations are complex to manage by nature, as they seek to address multi-faceted problems with limited resources in unstable operational environments. As needs evolve and new information comes in, it is therefore critical to continually monitor and understand each operation, quickly adapt and re-evaluate plans, optimize the use of limited resources, and anticipate what is expected to happen next.

To that end, WFP has been embracing the power of analytics. Engineers and mathematicians have taken a leading role in supporting complex operations, using analytics as an enabler to strengthen the integration between functional areas, augment visibility on WFP operations, and find concrete ways to maximize their efficiency and effectiveness. WFP was awarded in 2020 with the prestigious Franz Edelman Award for Achievement in Advanced Analytics, Operations Research and Management Science.

Biography

Sérgio Guedes Silva leads WFP's Supply Chain Planning service. A graduate in Mechanical Engineering and Management, Sérgio Guedes Silva decided to apply his engineering training to humanitarian causes.

He is leading a team responsible for innovations, operational support and strategic planning. Over the last few years he has been involved in humanitarian crises such as crises in Syria, Ethiopia, Sahel and Mozambique.

He is also the founder and current Council President of G.A.S. Porto, an NGO with around 400 volunteers, and is a regular guest speaker in several events in this field.

Sessão Plenária III

Dealing with uncertainty

Manuel Matos

INESCTEC, Faculdade de Engenharia da Universidade do Porto

Uncertainty affects our decision processes because in an uncertain environment we cannot completely anticipate the impact of our actions. The talk will review and comment some of the approaches used to represent and deal with uncertainty, from arbitrary clairvoyance to the simulation of nature status and of the decisions of others. Fuzzy numbers and intervals will be used to describe uncertain situations and show cases of artificial increase of uncertainty. The interaction of uncertainty with multiple criteria formulations will also be discussed. Illustrative examples will be provided, either general or from the power systems area (easy cases).

Bibliography

Manuel A. Matos was born in 1955 in Porto, Portugal. He is with the Faculty of Engineering of the University of Porto (FEUP), Portugal, since 1978 (Full Professor since 2000).

He is also coordinator of the Centre for Power and Energy Systems of INESC TEC and President of the Scientific Council of INESC TEC.

His research interests include classical and fuzzy modeling of power systems, reliability, planning, optimization and decision-aid, with application to renewable energy sources integration, electric vehicles' deployment and smart grids.

Sessão Plenária IV

How can we lift the practical relevance of our research in operations research?

Pedro Amorim

INESCTEC, Faculdade de Engenharia da Universidade do Porto

This presentation aims to discuss opportunities for our community to increase the practical relevance of its research. We'll start by discussing why practical research relevance matters for Operations Research. These opportunities will be discussed using a framework of suggestions, such as developing a practitioner advisory team or writing for practitioners in different mediums. We conclude by analyzing ways in which academic institutions can help in the persecution of this goal.

Biography

Pedro Amorim is an Assistant Professor (with habilitation) at Industrial Engineering and Management Department at FEUP and also an invited professor at Porto Business School. Since 2016, he's the Head of Research Center for Industrial Engineering and Management from INESC Technology and Science. He is also a co-founder of LTPlabs.

He was a visiting scholar IESE Business School (Spain) and at Carnegie Mellon University (USA) and he was a visiting researcher at Technical University of Berlin, Ingolstadt School of Management, University of São Paulo and Technical University of Lisbon. He leads a European Group focused on Retail.

In this domain he has conducted several projects applying advanced analytics to decision-making. He is also the author of more than 50 research papers published in international journals on Supply Chain Management, Retail Operations, and Optimization.

He holds a MSc and a PhD degree of Industrial Engineering and Management, from University of Porto, Portugal.

Resumos e Posters

Submissão #3

Uncertainty in Proton Therapy Treatment Planning Optimization


Joana Dias, Humberto Rocha, Brígida Ferreira, Joana Neves

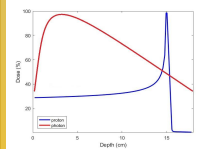
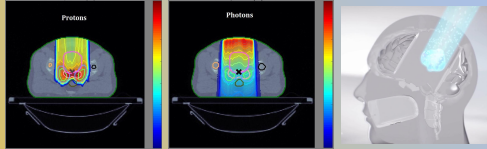
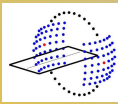


Radiotherapy treatment planning (RTP) is a research area where Operational Research and Medical Physics are a match made in heaven, with Operational Research being crucial for the improvement of treatment quality. RTP can be seen as a multiobjective optimization problem under uncertainty. In proton treatment, one of the most recent treatment modalities, tackling uncertainty in an explicit way is even more important than in other modalities. Proton beams have unique depth-dose characteristics. Protons slow down as they penetrate matter, their rate of energy transfer increases with depth, coming to an abrupt stop just beyond where energy deposition is maximum producing the so-called Bragg peak. By positioning several Bragg peaks inside the target volume, excellent tumor coverage is obtained, and adjacent organs at risk are spared. However, proton treatment is much more vulnerable to uncertainties due to high dose gradients. Continuing the conventional practice of defining safety margins around the tumour is not appropriate and robust optimization of treatment plans is necessary. In this work, different robust optimization approaches will be presented and compared, namely comparing absolute-robust models, where the objective is to look at the worst case scenario, with relative-robust approaches that consider the concept of regret.

Keywords: Radiotherapy Treatment Optimization, Optimization under Uncertainty, Robust Optimization

Uncertainty in Proton Therapy Treatment Planning Optimization

Joana Dias, Humberto Rocha, Brígida Ferreira, Joana Neves



<p>What is the core challenge of this work?</p> <ul style="list-style-type: none"> To improve the quality of radiotherapy (RT) treatments, namely considering an innovative technology: Proton Therapy We aim at contributing to treatment planning solutions that are scalable, reliable, fast, and cost-effective. This requires an interdisciplinary approach considering Medical Physics, Computer Science, OR, etc. Truly tailored radiation treatments can potentially contribute to increased cure or reduced incidence of severe radiation-induced morbidity. 	<p>Why is this challenging?</p> <ul style="list-style-type: none"> RT planning relies on a trial and error process. Proton therapy has specific features that make it highly appropriate for the treatment of cancer. However, it is much more vulnerable to uncertainties than other treatments. Proton range uncertainties, anatomy changes, setup variations can cause heterogeneities and misalignment of dose contributions from often highly modulated beams. Robust mathematical models and algorithms are crucial for dealing adequately with these uncertainties and improving treatment quality.
<p>Protons vs Photons With photons, you can see a lot of dose deposited before reaching the tumour while using protons there is little dose deposited before the tumour and almost none after.</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;">  </div> </div>	
<p>Robust Beam Angle Optimization</p> <ul style="list-style-type: none"> Determination of the optimal set of beams is a nonconvex mathematical problem, the space of solutions can be extremely large and full of local minima. Worst case based optimization vs Regret based optimization. Assessment using Monte-Carlo simulation, considering the impact of the treatment fractionation in the realized uncertainty. 	<p>Preliminary Results</p> <ul style="list-style-type: none"> Already treated prostate cancer cases after tumour removal surgery are being considered. Uncertainties impact tumour coverage more than organs at risk sparing. It is important to consider the number of treatment fractions in the assessment of the treatment plan. Regret-based stochastic optimization seems to provide better tumour coverage than worst case based models. More computational tests are still needed, considering also other cancer locations.
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<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="font-size: x-small;">  <p>This work has been supported by project grant POCI-01-0145-FEDER-028030, UTA-EXPL/FMT/0079/2019 and by the Fundação para a Ciência e a Tecnologia (FCT) under project grants UIDB/05037/2020 and UIDB/00308/2020.</p> </div> <div style="text-align: right;">  </div> </div>	

Submissão #4

The efficiency of nations in the fight against SARS-CoV-2: A network Data Envelopment Analysis

Miguel Pereira, Duarte Dinis, Diogo Ferreira, José Rui Figueira, Rui Marques

The current outbreak of SARS-CoV-2 has been having a major impact on health systems worldwide. Therefore, there is a need to understand the efficiency of the pandemic response across several nations and derive insights that can help governments and health authorities improve their national COVID-19 strategies. Thus, we conducted a network Data Envelopment Analysis (DEA) to estimate the efficiencies of fifty-five countries in the current crisis, designing the model as a general series structure with five single-division stages (population, contagion, triage, hospitalisation, and intensive care unit admission) and considering an output-maximisation orientation - to denote a social perspective - and an input-minimisation orientation - to denote an economic perspective. Our proposal considers inputs regarding health costs, desirable and undesirable intermediate products regarding the use of personal protective equipment and infected population, respectively, and desirable and undesirable outputs regarding COVID-19 recoveries and deaths, respectively. The study concludes that Estonia, Iceland, Latvia, Luxembourg, the Netherlands, and New Zealand are the countries that exhibit higher mean system efficiencies - their national COVID-19 strategies should be studied, adapted, and used by the countries that exhibit worse performances. Furthermore, we found statistical significance in the fact that countries with large populations present worse mean efficiency scores.

Keywords: Data Envelopment Analysis, Simulation, Series structure, SARS-CoV-2, Efficiency measurement

The efficiency of nations in the fight against SARS-CoV-2
A network Data Envelopment Analysis

Miguel Alves Pereira, Duarte Caldeira Dinis, Diogo Cunha Ferreira, José Rui Figueira, Rui Cunha Marques



<p>Intro</p> <ul style="list-style-type: none"> • By estimating the efficiency of different countries in the fight against the ongoing SARS-CoV-2 pandemic, it is possible to assess which health systems perform better and should be regarded as benchmarks, and which need to improve their performance. • Insights can then be obtained on the factors contributing to the best/worst performances, allowing governments to take the necessary measures in improving their respective health systems. 	<p>Methods</p> <ul style="list-style-type: none"> • We propose an approach based on network Data Envelopment Analysis (DEA) since, unlike conventional DEA, it considers the inner workings of entities. • The network is modelled through a general series structure with five single-division stages. • We also consider two model orientations: output-orientation, denoting a SOCIAL PERSPECTIVE, and input-orientation, denoting an ECONOMIC PERSPECTIVE. 	<p>Results</p> <ul style="list-style-type: none"> • Our analysis comprised 55 countries and 15 indicators capturing their reality from the beginning of the pandemic until 31/12/2020. • From both perspectives, no nations were systematic- or partially efficient, on average. • From an aggregate perspective, six nations performed at a Q1 level: Estonia, Iceland, Latvia, Luxembourg, the Netherlands, and New Zealand. 	<p>Discussion</p> <ul style="list-style-type: none"> • The reasons behind the success of BALTIC REPUBLICS resided in rapidly declaring a state of emergency, countering misinformation and disinformation, and enforcing physical-distancing requirements. • The LOW LANDS' success is due to applying decentralised "intelligent lockdowns" and massive testing-and-tracing. • The ISLANDS succeeded because of contact-tracing and isolation systems, and providing informed reports to the population.
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Original network DEA with simulation considering **desirable** and **undesirable** intermediate products and outputs.

No countries were able to **produce the largest amount of output for the same amount of input** or **produce the same amount of output using the least amount of input**.

Statistical significance was found in the association of **low mean system efficiencies in nations with large populations**.

The efficiencies of the SOCIAL PERSPECTIVE and the ECONOMIC PERSPECTIVE have a **positive moderate correlation**.

Only three pairings of countries showed **system efficiencies in Q1**: **BALTIC REPUBLICS** (Estonia and Latvia), **LOW LANDS** (Luxembourg and the Netherlands), and **ISLANDS** (Iceland and New Zealand).

Science-based decision-making was the **key to success** and partially explains the collapse of other countries.

Extra materials










Submissão #5

The family traveling salesman problem with incompatibility constraints

Raquel Bernardino, Ana Paias

Consider a depot and a partition of the set of nodes into subsets, called families. The objective of the family traveling salesman problem (FTSP) is to find the minimum cost route that starts and ends at the depot and visits a given number of nodes per family. We propose a new variant of the FTSP by introducing incompatibilities between the families, that is, incompatible families cannot be visited in the same route. Thus, the FTSP with incompatibility constraints (FTSP-IC) consists of determining the minimum cost set of routes that begins and ends at the depot; visits a given number of cities in each family; and does not visit incompatible nodes in the same route. We propose compact and non-compact formulations for the FTSP-IC, which model the incompatibility constraints for each family implicitly in compatibility graphs. We also present a new set of valid inequalities. To evaluate the different models, we used the benchmark instances for the FTSP and generated incompatibility matrices. The computational experiment shows that the non-compact models outperform the compact ones. We developed an iterated local search, which efficiently obtains solutions with a lower value than the branch-and-cut algorithm for the largest instances, with an unknown optimal value.

Keywords: Family traveling salesman problem, Branch-and-cut algorithm, Incompatibility constraints, Iterated local search algorithm




ANALYTICS FOR A BETTER WORLD

The family traveling salesman problem with incompatibility constraints

Raquel Bernardino* & Ana Paias*

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The FTSP-IC

► Given:

- a depot;
- a partition of the set of cities into families;
- a set of incompatible families; and
- a cost matrix, which represents the traveling costs between the depot and the cities and between each pair of cities.

► The FTSP-IC consists in finding the minimum cost set of routes that:

- begins and ends at the depot;
- visits a predefined number of cities in each family; and
- does not visit cities from incompatible families in the same route.

The RFV inequalities

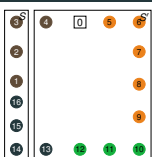
► If there exists a family $l \in \mathcal{L}$ such that the number of nodes in $S' = ((0) \cup C(l)) \setminus S$ and $S \subset C(l)$ is less than v_l , then there is an arc in the cut-set $\{S', S\}$ that has to be used in any feasible solution.

The rounded family visit (RFV) inequalities:

$$x(S', S) \geq 1, \quad (9)$$

$\forall l \in \mathcal{L},$
 $\forall S \subset C(l) : |S \cap F_l| \geq v_l - v_l + 1$

The 1st-DEG inequalities



- Families 1 and 4 are incompatible. Thus, the nodes from set S must be visited in two distinct routes.

The first degree incompatibility (1st-DEG) constraints:

$$x(S', S) \geq y_l + y_{l'}, \quad (10)$$

$\forall l, l' \in \mathcal{L} : (l, l') \in \mathcal{I},$
 $\forall S \subset C(l) \cup C(l'),$
 $\forall i, j \in S : i \in F_l \text{ and } j \in F_{l'}$
where $S' = ((0) \cup C(l) \cup C(l')) \setminus S.$

The Rounded 1st-DEG inequalities

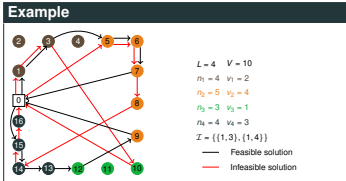
► If there are not enough nodes to complete the visits from family $l \in \mathcal{L}$ in S' we can replace in the 1st-DEG constraints the y_l associated with the node from family l by 1.

The rounded first degree incompatibility (Rounded 1st-DEG) constraints:

- $x(S', S) \geq 1 + y_{l'}$ (not enough nodes from family l in S')
- $x(S', S) \geq y_l + 1$ (not enough nodes from family l' in S')
- $x(S', S) \geq 2$ (not enough nodes from families l and l' in S')

where $S' = ((0) \cup C(l) \cup C(l')) \setminus S.$

Example



$L = 4, V = 10$
 $n_1 = 4, v_1 = 2$
 $n_2 = 5, v_2 = 4$
 $n_3 = 3, v_3 = 1$
 $n_4 = 4, v_4 = 3$
 $\mathcal{I} = \{(1, 3), (1, 4)\}$

— Feasible solution
 — Infeasible solution

Motivation

- The FTSP was proposed by Morán-Mirabal et al. (2014) and it was motivated by the order picking problem in warehouses with chaotic storage.
- Some types of products are incompatible with each other due to their nature (food and chemical products) and cannot be transported together. → Motivation for the FTSP-IC.

Infeasibilities

There are two types of infeasibilities:

- Type 1: Existence of subtours.
- Type 2: Existence of routes that contain incompatible nodes.

► We can simultaneously model subtour elimination constraints and incompatibility constraints by using connectivity constraints in the compatibility graph.

► The compatibility graph $G_c = (0 \cup C(l), A_c(l))$ is the subgraph induced by the nodes that are compatible with family $l \in \mathcal{L}.$

Formulation

$x_{ij} = 1$, if the arc $(i, j) \in A$ is used in any of the routes.
 $y_i = 1$, if the node $i \in N$ is visited in any of the routes.

Minimize $\sum_{(i,j) \in A} c_{ij} x_{ij}$ (1)

Subject to:

$$x(0, N) \geq 1, \quad (2)$$

$$x((0) \cup C(l), l) = y_l, \forall l \in N \quad (3)$$

$$x(l, (0) \cup C(l), l) = y_l, \forall l \in N \quad (4)$$

$$y(F_l) = v_l, \forall l \in \mathcal{L} \quad (5)$$

$$x(S', S) \geq y_k, \forall l \in \mathcal{L}, \quad (6)$$

$\forall S \subset C(l)$ and $S' = N \setminus S, \forall k \in S : k \in F_l,$

$$x_{ij} \in \{0, 1\}, \forall (i, j) \in A \quad (7)$$

$$y_i \in \{0, 1\}, \forall i \in N \quad (8)$$

Notation: $x(S', S) = \sum_{i \in S'} \sum_{j \in S} x_{ij}.$

Computational experiment - LP values

Instance	CC+RFV model			With Rounded 1st-DEG inequalities		
	gap	%	#CC	gap	%	#RFV
formal14	0.55%	0	7	0.00%	0	7
bayg29	2.38%	0	27	0.21%	0	33
att48	6.13%	0	151	0.49%	7	294
bw127	5.77%	7	624	2.65%	208	1343
average	3.71%	2	202	0.83%	54	419

*Instances with unknown optimal value

Computational experiment - Optimal values

Instance	CC+RFV model		With Rounded 1st-DEG inequalities	
	#Solved	% Total	#Solved	% Total
formal14	9/9	0	9/9	0
bayg29	9/9	0	9/9	0
att48	9/9	99	9/9	5
bw127	4/9	6478	7/9	3229
summary	31736	1644	3476	809

- We were unable to obtain the optimal values of any of the largest instances: **att60**, **g666** and **pr1002**.
- By using the Rounded 1st-DEG we were able to obtain the optimal value of three additional instances.

References

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Submissão #6

Models for a single vehicle continuous-time inventory routing problem with pickups and deliveries

Agostinho Agra, Marielle Christiansen, Laurence Wolsey

An inventory routing problem in which a single vehicle is responsible for the transport of a commodity from a set of supply locations to a set of demand locations is considered. At each location the inventory must be kept within predefined bounds, and the location specific supply and demand rates are constant throughout the time horizon. Each location can be visited several times during the time horizon, and the vehicle can visit the locations in any order as long as the capacity of the vehicle is not exceeded. Two models are presented, each defined on a different extended network. In a location-event model, the nodes are indexed by the location and the number of visits made so far to that location, while in a vehicle-event model the nodes are indexed by the location and the number of visits so far on the vehicle route. Both models are based on continuous time formulations. Bounds on the number of vehicle visits are discussed and a new branching algorithm is proposed. Computational tests based on a set of maritime transportation instances are reported to compare both models and test the new branching algorithm.

Keywords: Inventory, Routing, Strong formulations, Branching



We consider an inventory routing problem in which a single vehicle transports a commodity from a set of supply locations to a set of demand locations. The supply and demand rates at each location are constant throughout the time horizon. Each location can be visited several times during the time horizon, and the vehicle can visit the locations in any order as long as the capacity of the vehicle is not exceeded. At each location the inventory must be kept within predefined bounds. Two formulations are proposed.

The location-event formulation

In the location-event formulation, the vehicle path is defined on an extended graph in which each node corresponds to a visit to a location. For each location, we consider an ordering of the visits according to the time of the visit. A node is represented by a pair (i, m) in which i indicates the location and m indicates the m^{th} visit to location i . Arcs correspond to direct vehicle movements from node (i, m) to node (j, n) and are represented by (i, m, j, n) . The next figure shows a route of a vehicle that leaves the origin (node o) makes the first visit to location 3, then visits location 2 for the first time, returns to location 3, makes the first visit to location 1, then moves again to location 2, and goes to the dummy destination (node D).

The vehicle-event formulation

In this alternative formulation, events are linked to the vehicle. The order of the events corresponds to the order of the vehicle visits. The vehicle path is described using a layered graph in which each layer corresponds to the number of visits made by the vehicle. Each layer contains all locations. In the next figure we illustrate the path of the example given above in this layered graph, considering a maximum of eight visits.

Estimating the number of visits

The size of both models depends on the number of events (visits) which are not known in advance and need to be estimated. Large upper bounds for these parameters lead to large sized models. On the other hand, restricting the number of events too much may exclude optimal solutions. Here we propose to bound the number of events, for each model, by solving auxiliary problems, which coincide with the linear relaxation of the corresponding original model, where the original objective function (minimizing the total costs) is replaced by a new one maximizing the number of visits.

A two-level branching approach

As the number of visits plays a key role in solution procedures based on the mathematical models, we propose a new algorithm where we first branch on the number of visits and within each branch we solve the restricted model. The algorithm is as follows:

Algorithm 1.

1. Determine an upper bound u , for the number of visits
2. Add constraint: sum of visits $\leq \lfloor u/2 \rfloor$
3. Solve the resulting model with a time limit of β seconds
4. If a solution is found, set X_1 to the best feasible solution
5. Replace constraint in Step 2 by: $\lfloor u/2 \rfloor + 1 \leq \text{sum of visits} \leq u$
6. Solve the resulting model with a time limit of β seconds
7. If a solution is found, set X_2 to the best feasible solution
8. Choose between X_1 and X_2 .

If in the first branch of Algorithm 1 a feasible solution is found, then the value of the best feasible solution can be used as a cut-off value for the second branch.

Computational results

Computational tests were conducted on a set of 112 instances from a maritime inventory routing problem with a number of locations ranging from 3 to 6, and for time horizons of 60, 120, 180 and 240 days. Some of the instances are infeasible. Using the Xpress Optimizer, the results show that:

- Solving the branch-and-cut based on the vehicle-event model is, in general, faster than using the location-vehicle model both in feasible and infeasible instances (to prove infeasibility).
- Algorithm 1 is more efficient than applying the branch-and-cut to the full model on harder instances. For the easier instances, the difference between the two approaches is negligible.
- Using Algorithm 1 with the vehicle-event formulation and $\beta=3600$, all the instances with time horizon up to 120 days are solved to optimality and for 180 days only 4 are not solved.
- For the longest time horizons (180 and 240 days), the branching at the first level should be adjusted in order to construct two balanced subproblems.
- The inclusion of valid inequalities improved the running times but were not able to improve the linear relaxation bounds significantly.

Conclusions and future research

The proposed algorithm based on the vehicle-event formulation proved to be an efficient method to solve the single vehicle continuous-time inventory routing problem.

For future research we propose the following research lines:

- Derive new valid inequalities incorporating the different problem characteristics (routing, inventory, capacities, etc.).
- Study new branching schemes based on the number of visits.
- Extend the proposed models to deal with multiple vehicles.

Reference

Agostinho Agra, Marielle Christiansen, Laurence Wolsey Improved models for a single vehicle continuous-time inventory routing problem with pickups and deliveries. *European Journal of Operational Research*, 201, 2, 164-170, 2022.


Submissão #7

Defining hospital networks with centralized waiting lists for elective patients


Mariana Oliveira, Daniel Santos

Long waiting lists for elective surgery can be a consequence of the inability of hospitals to provide timely care, which may happen due to lack of physical or human resources or due to inefficiencies in the management of elective patients. This research work aims to identify the main sources of problems in the strategic planning of operating rooms, particularly on waiting list management. For this purpose, an optimization model to support decisions about waiting list pooling agreements among hospitals is proposed. This model allows to compare the performance of individual hospitals when waiting lists are centralized at different levels. The network system perspective grants the opportunity to reduce costs and increase compliance with each individual hospital's strategic missions, as waiting time targets are considered and, consequently, improved quality of care is pursued.


Keywords: Health services, Strategic decisions, Optimization



TÉCNICO LISBOA




APDIO




io2021


Defining hospital networks with centralized waiting lists for elective patients



CEGIS



OpLog



FCT

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Highlights

Research question:
Can a centralized waiting list for elective patients improve access to surgical care in terms of waiting time and tardiness, while keeping acceptable distances between hospitals?

Decision:
Form clusters of hospitals that allow to better balance surgical demand and supply

Impact:
Informed policy-making and resource allocation decisions

Model

$$\min \sum_{t \in T} \sum_{c \in C} d_{tc} \theta_{tc} \quad (1)$$

$$\text{s.t.} \sum_{t \in T} \theta_{tc} = 1 \quad \forall t \in T, c \in C \quad (2)$$

$$F_{tc} + F_{ct} - 2\theta_{tc} d_{tc} \leq 1 \quad \forall t \in T, c \in C, h_1, h_2 \in H, h_1 \neq h_2 \quad (3)$$

$$F_{tc} + F_{ct} \geq 2\theta_{tc} d_{tc} \quad \forall t \in T, c \in C, h_1, h_2 \in H, h_1 \neq h_2 \quad (4)$$

$$\alpha_{tc} \theta_{tc} \leq \beta \quad \forall t \in T, c \in C, h_1, h_2 \in H, h_1 \neq h_2 \quad (5)$$

$$\sum_{t \in T} d_{tc} \theta_{tc} \geq \sum_{h \in H} d_{th} \theta_{th} \quad \forall t \in T, c \in C \quad (6)$$

$$\sum_{t \in T} (d_{tc} - \alpha_{tc}) \theta_{tc} \leq \theta_{tc} \quad \forall t \in T, c \in C \quad (7)$$

$$\sum_{t \in T} (\alpha_{tc} - d_{tc}) \theta_{tc} \leq \theta_{tc} \quad \forall t \in T, c \in C \quad (8)$$

$$\theta_{tc} \geq 0 \quad \forall t \in T, c \in C \quad (9)$$

$$F_{tc}, \theta_{tc} \in \{0, 1\} \quad \forall t \in T, c \in C, h_1, h_2 \in H \quad (10)$$

Introduction

Motivation:

- Elective surgical demand increase
- General resource restriction
- Pressure to increase production
- Improve patients' experience

Objectives:

- Redesign surgical planning processes
- Support strategic decisions
- Balance surgical demand and supply
- Reduce waiting time and burden for patients
- Establish networks of hospitals to better coordinate response to surgical demand

Preliminary Results

Number of clusters

- * 1 → Completely centralized
- * Number of hospitals → Completely decentralized

Model validation (running time limit of 1 hour)
Assuming one specialty and a maximum number of clusters equal to the number of hospitals, these were some of the obtained results:

Instance	Time	Hospitals	Initial imbalance	Final imbalance	Max clusters	Min clusters
1	6	4	88344	2277	2	1
2	12	8	665472	13540	8	4
3	3	2	11040	1280	1	1
4	3	17	90066	3418	6	5
5	12	5	420900	10561	5	3
6	3	11	55968	1161	3	2
7	6	23	471822	5004	7	2
8	3	28	147840	2502	12	9
9	12	1	85568	3095	1	1
10	4	10	97960	5772	7	3

Conclusions

- The model was able to reduce imbalance between supply and demand for every generated instance.
- Centralized waiting lists within hospital clusters might reduce imbalance between supply and demand and, consequently, reduce waiting time for patients and tardiness of surgeries.
- However, for most cases, the optimal solution does not involve completely centralized waiting lists. Thus, this decision should be made in an informed manner.

Notation

Indices and Sets

- $h \in H$ hospitals
- $c \in C$ clusters
- $t \in T$ time periods

Parameters

- d_{th} demand for hospital h in time period t
- w_{th} capacity for hospital h in time period t
- $\alpha_{h_1 h_2}$ distance between hospital h_1 and hospital h_2
- β maximum allowed distance between hospitals within the same cluster
- θ minimum ratio demand/supply that must be guaranteed in a cluster

Decision variables

- F_{tc} 1, if hospital h belongs to cluster c in time period t , 0, otherwise


Auxiliary variables


- d_{tc} imbalance between demand and capacity for cluster c in time period t
- θ_{tc} 1, if hospital h_1 and h_2 belong to cluster c in time period t , 0, otherwise


Next steps

- Incorporate patient clustering techniques to classify different types of demand
- Combination with simulation, assess how flexibility in human resources among hospitals could impact the results regarding waiting time of patients
- Comparison between deterministic and stochastic approaches: incorporate uncertainty into demand and capacity parameters
- Refine capacity measures
- Add objective to minimize distance between hospitals within the same cluster

Acknowledgements
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Submissão #8

Um método exato para problemas bilevel lineares com múltiplas funções objetivo no nível inferior

Maria João Alves, Carlos Henggeler Antunes

Neste trabalho consideramos problemas de otimização em dois níveis (bilevel) lineares com múltiplas funções objetivo no nível inferior. Propomos um método exato para calcular a solução ótima da formulação otimista do problema, que se baseia na transformação do problema original num problema de programação linear multiobjetivo (PLMO) equivalente. A solução ótima é obtida através da pesquisa de soluções eficientes extremas do problema de PLMO. Para o efeito, foi desenvolvido um algoritmo que calcula todas as bases eficientes deste problema equivalente. Como o problema de PLMO pode ter um número elevado de funções objetivo, o qual depende do número de variáveis de nível superior do problema bilevel, o esforço computacional para obter a solução ótima pode ser significativo. No entanto, este método tem a vantagem de fornecer sempre uma solução admissível do problema bilevel quando é considerada uma limitação do tempo computacional que não permite terminar a respetiva execução, o que não acontece em outros métodos da literatura. É apresentada uma comparação entre este novo método e outro algoritmo exato de referência proposto por outros autores, enfatizando as vantagens e desvantagens de cada um dos métodos.

Palavras chave: Programação multiobjetivo, Otimização bilevel, Método simplex multiobjetivo

UM MÉTODO EXATO PARA PROBLEMAS BILEVEL LINEARES COM MÚLTIPLAS FUNÇÕES OBJETIVO NO NÍVEL INFERIOR

PROBLEMA (BLMO)

$$\begin{aligned} \max_{x,y} \quad & F(x,y) = c^1x + d^1y \\ \text{s.a.} \quad & A^1x \leq b^1 \\ & x \geq 0 \\ \max_y \quad & f_i(y) = d_i^2y \quad i = 1, \dots, p \\ \text{s.a.} \quad & A^2x + B^2y \leq b^2 \\ & y \geq 0 \end{aligned}$$

Líder: controla $x \in R^{n_1}$
Seguidor: controla $y \in R^{n_2}$

Solução **ótima otimista:** otimiza $F(x,y)$ na **região induzida:** $IR = \{(x,y) \in S: y \in \Psi_{ef}(x)\}$
 $S = \{(x,y): A^1x \leq b^1, A^2x + B^2y \leq b^2, x,y \geq 0\}$ → região das restrições
 $\Psi_{ef}(x)$ → todas as soluções eficientes de $MOLL(x)$, problema **multiobjetivo** do seguidor para um dado x .

Sabe-se que:

- IR é composta pela união de faces de S
- Uma/a solução ótima de BLMO está num vértice de IR

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ANALYTICS WORLD
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RESULTADO TEÓRICO

Problema multiobjetivo substituto (com $p = n_1 + 1$ funções objetivo):

$$\begin{aligned} \max \quad & f_j(y) = d_j^2y \quad j = 1, \dots, p \\ \max \quad & x_i \quad i = 1, \dots, n_1 \\ \max \quad & \sum_{i=1}^{n_1} (-x_i) \end{aligned}$$

s.a. $(x,y) \in S$

Proposição: (x',y') é admissível de BLMO (i.e., pertence a IR) sse é uma solução eficiente do problema PMOS.
Corolário: existe pelo menos uma solução extrema (vértice) eficiente de PMOS que é ótima de BLMO.

VE ✈️ **K-th BEST**

Algoritmo VE: Pesquisa 6 bases em IR (incluindo bases degeneradas) e escolhe a melhor: ponto A

Algoritmo k-th best: Pesquisa 11 bases em S (incluindo bases degeneradas) até chegar a IR: ponto A

Algumas resultados computacionais:

Problema	P*	VE		k-th best	
		#bases	tempo (s)	#bases	tempo (s)
a_5_10_10	616.76	282	0.26	340	0.36
b_5_10_10	1016.68	335	0.33	29	0.02
c_5_10_10	386.19	143	0.12	269	0.23
d_5_10_10	493.93	395	0.39	389	0.40
a_10_20_20	2598.90	>10000	762.2	>10000	575.7
b_10_20_20	>10000	710.3	1730.10	>10000	576.2
c_10_20_20	>10000	405.4	2932.42	>10000	576.2
d_10_20_20	3692.22	>10000	502.2	29186	65.5
a_5_50_50	>10000	535.9	3614.24	>10000	450.9
b_5_50_50	>10000	564.6	5940.82	>10000	707.0
c_5_50_50	>10000	516.6	8000.70	>10000	504.6
d_5_50_50	>10000	516.65	2342.89	>10000	522.6

ALGORITMO PROPOSTO (VE)

Baseado no corolário, pesquisa todos os vértices eficientes de PMOS e seleciona o ponto com maior $F(x,y)$:

- Calcula uma 1ª base eficiente de PMOS, B^0 (otimizandando uma soma pesada) e insere B^0 na lista L_B
- Determina todas as bases B eficientes adjacentes a B^0 . Se $B \notin L_B$, então $L_B \leftarrow L_B \cup \{B\}$.
- Repete 2) para cada $B \in L_B$

ALGORITMO K-th BEST^[5]

- Otimiza $F(x,y)$ em $S \rightarrow sol.candidata$
- Verifica se a $sol.candidata$ é eficiente de $MOLL(x')$ resolvendo um problema PL auxiliar
 - Se for, termina: ótimo de BLMO
 - Senão, calcula todas as soluções básicas de S adjacentes à anterior; insere-as na lista Q
- Escolhe a solução de Q com maior $F(x,y)$ para $sol.candidata \rightarrow ii$

CONCLUSÕES

- Principal desvantagem de VE: o esforço computacional cresce muito com n_1 .
- Principal vantagem de VE: ao contrário do k-th best, pode ser usado parcialmente para encontrar uma aproximação da solução ótima de BLMO porque devolve sempre uma solução admissível.
- O algoritmo VE pode ser usado para calcular todas as soluções extremas eficientes de um qualquer problema de PL multiobjetivo.

[5] Galvão, H. and Galá, C. (2011) "On linear bilevel problems with multiple objectives at the lower level." Omega, 29(1), pp. 35-40.

Submissão #9

The determination of sets of short and dissimilar paths

Marta Pascoal, Maria Teresa Godinho, Ali Moghanni

We address the problem of finding sets of K paths, with K a given integer, that simultaneously consider two criteria: the minimization of the total cost of the paths and the maximization of the dissimilarity between them. The purpose of these objectives is to find low cost/distance/time solutions, but which are also fairly different from one another, which are relevant considerations in applications that range from hazardous materials transportation to cash collection. Two approaches are used to measure the dissimilarity of a set of paths: the extent of the overlap of the paths, in terms of the number of times that each arc appears in more than one of them; and the number of times that the arcs shared by two or more paths appear in that solution. The bi-objective problems resulting from each of these approaches are modeled in terms of integer linear programs, and ϵ -constraint methods are then designed to solve them. Finally, computational experiments compare the results obtained by the two approaches in terms of the efficiency regarding computational time and of the dissimilarity of the efficient solutions for each problem.

Keywords: K alternative paths, Cost, Dissimilarity, IP formulations, Bi-objective optimization

Finding K shortest and dissimilar paths

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Motivation

Paths linking a pair of nodes may have common parts - see the blue and red paths below. However, for applications from hazardous materials transportation, money collection or telecommunications, it is important to have alternatives that share few network resources, privileging paths like the green and the red (or blue). This characteristic is known as dissimilarity and is often defined depending on the application.

Paths between a pair of nodes

Method

M_1 and M_2 (M_3) are conflicting criteria, therefore we find a set of non-dominated points for each model.

ϵ -constraint algorithm

$(y_1^*, y_2^*) \leftarrow$ ideal point for (f_1, f_2)
 $(y_1^N, y_2^N) \leftarrow$ nadir point for (f_1, f_2)
 $Y_\epsilon \leftarrow \{(y_1^i, y_2^i)\}; x \leftarrow (y_1^i, y_2^i)$
 $\epsilon \leftarrow y_2^N - \Delta$
while $\epsilon \geq y_2^i$ **do**
 $x^* \leftarrow$ optimal solution for f_1 of the constrained problem where $f_2(x) \leq \epsilon$
 $\epsilon \leftarrow$
if $f_1(x^*) > f_1(x)$ **then**
 $Y_\epsilon \leftarrow Y_\epsilon \cup \{(f_1(x), f_2(x))\}$
 $x \leftarrow x^*$
 $\epsilon \leftarrow f_2(x^*) - \Delta$
 $Y_\epsilon \leftarrow Y_\epsilon \cup \{(f_1(x), f_2(x))\}$

Y_ϵ stores the non-dominated points as they are computed.
 f_1, f_2 are set as M_3, M_1 , respectively, when solving BMAR, or M_3, M_2 , respectively, when solving BMAO, because M_1 (M_2) has a smaller range than M_3 .
 $\Delta = 1$ because M_1 (M_2) is integer.

Results

Number of non-dominated points and run times (secs)

	BMAR		BMAO	
	Y_ϵ	T	Y_ϵ	T
$R_{100,5}$	40.8	3.2	215.8	215.9
$R_{100,15}$	53.2	6.9	248.4	368.7
$R_{100,15}$	51.9	6.6	245.0	596.4
$R_{500,5}$	70.1	25.0	303.5	6259.2
$R_{500,15}$	71.0	96.6	259.1	9 634.0
$R_{500,15}$	71.4	206.1	158.7	5 729.5

	BMAR		BMAO*	
	Y_ϵ	T	Y_ϵ	T
$G_{12,12}$	219.1	564.9	1 334.2	3 628.8
$G_{4,36}$	131.8	391.4	1 716.5	20 237.7
$G_{15,15}$	327.6	337.5	1 873.2	4 559.7
$G_{5,45}$	205.6	427.3	2 197.5	20 560.3

* Sub-problems halted after 500 seconds.

Cost-dissimilarity and decrease of BMAR with respect to BMAO [%]

BMAR was faster than BMAO. It found fewer points and solved easier sub-problems. Besides:

- In random instances BMAO produced solutions with better dissimilarities and a wider costs range.
- In grids BMAO produced more dissimilar solutions. In square grids BMAR led to a wider costs range; the opposite occurred in rectangular grids.

Both models are complementary and useful for finding sets of dissimilar and short paths.

Goal

Given a network (N, A) with $c_{ij} > 0$, $(i, j) \in A$, and X the set of K paths from $s \in N$ to $t \in N$, we address the determination of solutions in X , with goals:

- minimize the path's cost
- minimize their similarity

where similarity is modelled as:
 BMAR the number of arc reuses
 BMAO the number of arc overlaps.
 Both can be modelled by ILPs in X . In BMAR we minimize:

$$M_3 = \sum_{(i,j) \in A} c_{ij} f_{ij}, M_1 = \sum_{(i,j) \in A} u_{ij}$$

with f_{ij} the number of occurrences of (i, j) , and u_{ij} its number of reuses. In BMAO we minimize:

$$M_3 = \sum_{(i,j) \in A} c_{ij} \sum_{p=1}^K g_{ij}^p$$

$$M_2 = \sum_{(i,j) \in A} \sum_{p=1}^K \binom{p}{2} g_{ij}^p$$

where $g_{ij}^p = 1$ iff $(i, j) \in A$ appears in p paths, or $g_{ij}^p = 0$ otherwise.

Proposition 1 Efficient solutions of BMAR (BMAO) are loopless.

Tests

BMAR and BMAO run with CPLEX 20.1 on a PC @3.7GHz, 128GB of RAM. The results are averages for $K = 20$ on 20 instances of each type:

- Random graphs, $R_{n,d}$, with $n = 100, 500$ nodes and $m = dn$ arcs, $d = 5, 10, 15$.
- Grids, $G_{p,q}$: $p \times q = 4 \times 36, 12 \times 12, 5 \times 45, 15 \times 15$.

For $(i, j) \in A$, $c_{ij} \in \{1, 2, \dots, 100\}$. The comparison focuses the number of non-dominated points ($|Y_\epsilon|$) and the run time (T). The sets of K paths are also compared for M_3 and the average dissimilarities (D), based on:

$$D(p, \rho) = 1 - \frac{1}{2} \left(\frac{L(p \cap \rho)}{L(p)} + \frac{L(p \cap \rho)}{L(\rho)} \right)$$

with $L(p)$ the number of arcs in p .

References

Moghanni, Pascoal, Godinho (2020). Finding K dissimilar paths with discretized integer linear formulations. Submitted.
 Moghanni, Pascoal, Godinho (2021). Finding K shortest and dissimilar paths. IOR, <http://doi.org/10.1111/itor.13866>.

Submissão #10

Crew rostering with fair satisfaction of personal preferences

Ana Wemans, Ricardo L. Saldanha

We address the personalised crew rostering problem in a context where each employee has its own skills, seniority and preferences and where optimisation goals include covering as much work as possible, maximise preference satisfaction and fairness. Previous work addressed only two extreme particular cases: the case where fairness means equal distribution of preference satisfaction, which is only valid in contexts where all employees prefer the same thing, or the case where fairness means uneven distribution but according to strict seniority, which is a context where employees don't really compete among themselves for the same work assignments. We propose an approach based on large neighbourhood search, dynamic programming, integer programming and a multi-item auction model for addressing a more generic case where employees may prefer different things and where seniority may not be strict. We evaluate the approach with real world data.

Keywords: Personalised crew rostering, Fairness, Crew preferences

Crew Rostering with Fair Satisfaction of Personal Preferences

Ana Wemans and Ricardo L. Saldanha, SISCOG – Sistemas Cognitivos, SA

Motivation

The major goal is to improve employee retention levels and motivation by introducing work-life balance concerns in the planning of crew rosters.

Examples of employee requests (preferences):

- Leaving earlier on a specific day to celebrate a birthday
- Starting after 9am everyday to leave the kids at school before

Challenge

- Algorithmic support for producing **personalized crew rosters** that maximize work covered, preference satisfaction and fairness
- Fairness addressed in a context where **employees may have different preferences** and seniority may not be strict, which is **new in the literature**
- Previous work addressed particular cases
 - Different preferences but strict seniority (no competition between employees)
 - Seniority is not strict but all employees have the same preferences
- Test the algorithm with real world data in a simulated production environment
- Algorithm integrated in CREWS(*)

Solution Method

Compute fair preference satisfaction targets for each employee

Build initial solution with a greedy heuristic using dynamic programming [2]

Improve solution With large neighbourhood search using Wedelin's Heuristic [1]

No improvement? Time limit reached?

Yes ↓ Leave

Objective function

- Maximize work covered
- Minimize mean square error of employee satisfaction with respect to target

- Uses a **Multi-item auction** [3] model that simulates employees bidding for their preferred work assignments
- **Fairness** is assured by providing employees with the same amount of coins to spend
- More preference requests means less strength for each request

Results and conclusions

Table 1 shows the **results** of running our algorithm in scenarios where employees prefer the same thing (1.x) or different things (2.x) and where preference satisfaction is activated or not and is combined or not with other goals, namely even distribution of workload (seniority).

Fairness is measured by the standard deviation of preference satisfaction (smaller standard deviation means that preferences are more evenly distributed).

Instance	Sta pref Early duties	Sta pref Late duties	Sta pref Night duties	Seniority?	Sat pref Fairly goal	Distribution Work Evenly goal	Pref sat Avg (ub)	Pref sat avg	Pref sat std	Workload std
1.1	100%	0%	0%	✗	✗	✗	36.61%	36.61%	18.98	-
1.2	100%	0%	0%	✗	✗	✗	36.61%	36.61%	2.19	-
1.3	100%	0%	0%	✓	✓	✗	36.61%	36.61%	18.36	-
2.1	33%	33%	33%	✗	✗	✗	66.55%	25.98%	14.31	4.48
2.2	33%	33%	33%	✗	✓	✗	66.55%	60.68%	2.27	5.98
2.3	33%	33%	33%	✗	✗	✓	66.55%	23.90%	13.25	0.42
2.4	33%	33%	33%	✗	✓	✓	66.55%	48.80%	8.62	0.49

Table 1: Computational results

The following **conclusions** can be drawn:

- This model **increases the global satisfaction** (2.2 vs 2.1) (1.2 vs 1.1)
- The model **increases the fairness** in preference satisfaction (1.2 vs 1.1)
- The model **performs well when combined with other objectives** (2.4 vs 2.2 and 2.3)

References and footnotes:

[1] D. Wedelin. An algorithm for large scale 0-1 integer programming with application to airline crew scheduling. *Ann. Oper. Res.* 57(1), 1995.

[2] S. Irnich et al. Shortest path problems with resource constraints. *Column Generation*. Springer, 2005.

[3] Gabriella Demange et al. Multi-item auctions. *J Public Econ*, 94(4), 1986.

(*) CREWS is a software product developed by SISCOG for scheduling the work of crew in railways and subways. www.siscog.pt

Submissão #11


Um conjunto abrangente e modular de modelos MILP da operação de cargas para otimização da resposta dinâmica da procura de energia elétrica

Carlos Henggeler Antunes, Maria João Alves, Inês Soares

A resposta dinâmica da procura permite acomodar maior quantidade de geração de energia elétrica de origem renovável, por sua vez essencial para descarbonizar a economia e mitigar o aquecimento global. Os consumidores/prosumers estarão cada vez mais expostos a preços de energia diferenciados no tempo, destinados a induzir mudanças nos padrões habituais de consumo. Os modelos de otimização a implementar em sistemas autónomos de gestão de energia requerem uma representação rigorosa do funcionamento das cargas para obter soluções respeitando os seus princípios físicos de operação e padrões habituais de uso. Neste contexto, é necessário um equilíbrio entre o detalhe dos modelos e os requisitos computacionais para gerar soluções em processadores de baixo custo. Esta comunicação apresenta um conjunto abrangente e modular de modelos de programação linear inteira mista, permitindo a sua incorporação em sistemas de gestão de energia para a otimização integrada de todos os recursos energéticos (trocas com a rede, gestão de cargas, veículo elétrico e bateria estacionária, microgeração local). São apresentados modelos de otimização para cargas cuja operação pode ser deslocada no tempo, interruptíveis e termostáticas. Estes modelos podem ser utilizados de forma modular em modelos globais com diferentes funções objetivo considerando as dimensões económica e de conforto.

Palavras chave: Resposta dinâmica da procura, Modelação de cargas, Programação linear inteira mista

Um conjunto abrangente e modular de modelos MILP da operação de cargas para otimização da resposta dinâmica da procura de energia elétrica




Carlos Henggeler Antunes^{1,3}, Maria João Alves^{2,3}, Inês Soares³

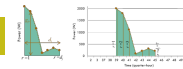
¹ Dep. Eng. Eletrotécnica e de Computadores, Univ. de Coimbra ; ² CeBER e Faculdade de Economia, Univ. de Coimbra ; ³ INESC Coimbra

Contexto

- Resposta dinâmica da procura permite acomodar mais geração renovável
- Consumidores/prosumers expostos a preços de energia diferenciados no tempo → induzir mudanças nos padrões habituais de consumo
- Modelos de otimização a implementar em sistemas autónomos de gestão de energia (AHEMS) → representação rigorosa do funcionamento das cargas para obter soluções respeitando os princípios físicos de operação e padrões habituais de uso
- Equilíbrio entre o detalhe dos modelos e os requisitos computacionais para gerar soluções em processadores de baixo custo funcionando continuamente
- Otimização integrada de todos os recursos energéticos: trocas com a rede, gestão de cargas, veículo elétrico e bateria estacionária, microgeração local
- Modelos de otimização para cargas: 1) cuja operação pode ser deslocada no tempo, 2) interruptíveis, 3) termostáticas
- Utilização modular em modelos globais com diferentes funções objetivo: dimensões económica e de conforto



Cargas deslocáveis



Slot de conforto do consumidor: $[T_{rj}, \dots, T_{rj}]$ [podem existir múltiplos slots]

Modelo 1: $s_{jt} = 1$, se a carga j inicia o funcionamento em t
 $j = 1, \dots, J; t = T_{rj}, \dots, T_{rj} - d_j + 1$

$s_{jt} = 1, j = 1, \dots, J$

$p_{jt}^{on} = \sum_{r=1}^{T_{rj}-d_j+1} \theta_{jr} s_{jt} (t-r+1), j = 1, \dots, J, t = T_{rj}, \dots, T_{rj}$

$p_{jt}^{off} = 0, j = 1, \dots, J, t < T_{rj} \forall t > T_{rj}$

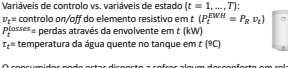
$s_{jt} \in \{0,1\}, j = 1, \dots, J, t = T_{rj}, \dots, T_{rj}$

Modelo 2: variáveis de controlo $w_{jrt} = 1$ se a carga j está on na fase r do seu ciclo de operação em t (dentro do slot de conforto).

Restrições para modelar a operação de cargas deslocáveis:

- se a carga j está on em t e na fase $r < d_j$ do ciclo de operação, então deve estar on em $t+1$ e fase $r+1, r = 1, \dots, (d_j - 1)$
- cada carga j funciona uma única vez na fase r e dentro do slot de conforto
- a carga j deve iniciar o funcionamento o mais tarde em $T_{rj} - d_j + 1$ de um slot de conforto, assegurando que não acaba depois de T_{rj} .

Cargas interruptíveis – Aquecedor de água (EWH)



Variáveis de controlo vs. variáveis de estado ($t = 1, \dots, T$):
 s_t = controlo on/off do elemento resistivo em t ($P^{EWH} = P_R s_t$)
 P^{losses} = perdas através da envolvente em t (kW)
 τ_t = temperatura da água quente no tanque em t (°C)

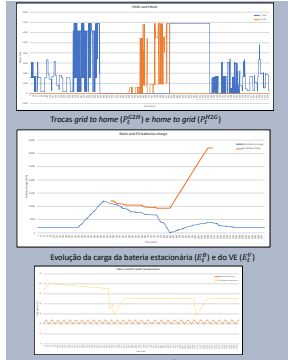
O consumidor pode estar disposto a sofrer algum desconforto em relação a uma gama de conforto da temperatura da água ($\tau_{confort}^{min}, \tau_{confort}^{max}$), penalizando o respetivo desvio na função objetivo.

O estado on/off considera a retirada de água de acordo com um dado padrão de consumo, temperatura da água da rede, perdas através da envolvente.

Para além das trocas térmicas consideram-se restrições sanitárias: aquecer a água a uma dada temperatura durante um tempo especificado.

O Modelo 2 tem mais variáveis, mas as restrições são mais legíveis.

	Modelo 1	Modelo 2
# var. binárias	1360	13004
# var. contínuas	4320	4320
Cont. (segundos)	15.5635	15.5635
# funções IO	0,564	156,466




Trocas grid to home (P^{grid}) e home to grid (P^{hg})

Evolução da carga da bateria estacionária (B^E) e do VE (E^V)

Evolução da temperatura interior (θ^i) e do EWH (τ_t)

Cargas termostáticas – AC



Variáveis de decisão e auxiliares ($t = 1, \dots, T$):
 s_t = variáveis de controlo on/off
 θ_t^i = temperatura interior (°C)
 y_t, z_t = variáveis binárias para modelar as condições lógicas de funcionamento do termostato com histerese:

$y_t = 1$ if $\theta_t^i < \theta^{min}$
 $z_t = 1$ if $\theta_t^i > \theta^{max}$

$\theta_t^i = (1 - \beta) \theta_t^{i-1} + \beta \theta_{t-1}^{i-1} + \gamma P^{AC} s_{t-1}$
 $\theta_t^i \geq \theta^{min} - M s_t$
 $\theta_t^i \leq \theta^{max} + M z_t$
 $\theta_t^i \geq \theta^{min} - M y_t$
 $z_t + y_t - s_{t-1} + s_t \leq 2$
 $z_t + y_t + s_{t-1} - s_t \leq 2$
 $\theta_t^i \leq \theta^{max} + M(1 - s_t)$

$t = 1, \dots, T$

Submissão #12

How to reach an optimized and sustainable Blood Supply Chain network?

Ana Torrado, Ana Barbosa-Póvoa

Blood has a prominent role in human life. However, blood is scarce, perishable and not replaceable. Blood donation system must deliver enough supply of blood to the hospitals. An effective collection of blood from donors and a suitable blood production is vital to satisfy the Blood Supply Chain (BSC), to optimize a fair blood usage and, consequently, to reduce shortages, outdates and wastage. In this work we develop a location-allocation model for the design of a sustainable and strategic-tactical BSC. We aim a balancing production of the different blood types, considering the social and the costs dimensions. The model incorporates the blood donor's allocation to the different facilities; the patient's allocation (while receiving RBCs, PLTs, PLS) to the healthcare facilities and the remaining capacity for satisfying demand and supply. Data available in the NHS of Portugal illustrates the applicability of the proposed model, serving as a validation tool.

Keywords: BSC, Sustainability, Location-Allocation, MILP, Optimization



TÉCNICO LISBOA



CEGIST

How to reach an optimized and sustainable Blood Supply Chain network?

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Motivation

- Blood Supply Chain (BSC) network presents different phases, such as the blood collection, testing, processing, inventory, distribution processes and transfusion (Belien and Forcé 2012; Osorio et al. 2015).
- As a result of collection alternatives, different geographical situations and the growing of costs (e.g., shortage, storage, social), achieving an optimal and sustainable BSC network design (BSCND) is challenging.
- Regarding the social indicators, literature tends to dedicate attention to the number of fixed and variable jobs. Concerning the environment indicators, there is the need to evaluate the environmental impacts caused, e.g., by establishing the different infrastructures/shipping the blood units, wasted blood units.

Research Questions

- Where to locate and how to allocate the blood facilities to satisfy demand/supply in a sustainable way?
- How to incorporate social indicators and cost concerns in the sustainable BSC design?



Model

- MILP formulation focused on the location-allocation problem



Key aspects of the model:

- 1st stage:** Minimize the total cost of travelling from a district to a facility with blood services, adding additional blood services and the total cost of adding extra capacity.
- 2nd stage:** Find the product flow from blood centers to hospitals with blood services which has minimum production and transportation costs.
- Constraints:** Demand (facilities), Supply (facilities), Blood facilities capacities, Additional blood facilities capacities, Production capacity, Production rate constraint.

Results




District	Red Cells	Platelets	Plasma	Address
01	10	10	10	10
02	15	15	15	15
03	20	20	20	20
04	25	25	25	25
05	30	30	30	30
06	35	35	35	35
07	40	40	40	40
08	45	45	45	45
09	50	50	50	50
10	55	55	55	55
11	60	60	60	60
12	65	65	65	65
13	70	70	70	70
14	75	75	75	75
15	80	80	80	80
16	85	85	85	85
17	90	90	90	90
18	95	95	95	95
19	100	100	100	100
20	105	105	105	105
21	110	110	110	110
22	115	115	115	115
23	120	120	120	120
24	125	125	125	125
25	130	130	130	130
26	135	135	135	135
27	140	140	140	140
28	145	145	145	145
29	150	150	150	150
30	155	155	155	155
31	160	160	160	160
32	165	165	165	165
33	170	170	170	170
34	175	175	175	175
35	180	180	180	180
36	185	185	185	185
37	190	190	190	190
38	195	195	195	195
39	200	200	200	200
40	205	205	205	205
41	210	210	210	210
42	215	215	215	215
43	220	220	220	220
44	225	225	225	225
45	230	230	230	230
46	235	235	235	235
47	240	240	240	240
48	245	245	245	245
49	250	250	250	250
50	255	255	255	255
51	260	260	260	260
52	265	265	265	265
53	270	270	270	270
54	275	275	275	275
55	280	280	280	280
56	285	285	285	285
57	290	290	290	290
58	295	295	295	295
59	300	300	300	300
60	305	305	305	305
61	310	310	310	310
62	315	315	315	315
63	320	320	320	320
64	325	325	325	325
65	330	330	330	330
66	335	335	335	335
67	340	340	340	340
68	345	345	345	345
69	350	350	350	350
70	355	355	355	355
71	360	360	360	360
72	365	365	365	365
73	370	370	370	370
74	375	375	375	375
75	380	380	380	380
76	385	385	385	385
77	390	390	390	390
78	395	395	395	395
79	400	400	400	400
80	405	405	405	405
81	410	410	410	410
82	415	415	415	415
83	420	420	420	420
84	425	425	425	425
85	430	430	430	430
86	435	435	435	435
87	440	440	440	440
88	445	445	445	445
89	450	450	450	450
90	455	455	455	455
91	460	460	460	460
92	465	465	465	465
93	470	470	470	470
94	475	475	475	475
95	480	480	480	480
96	485	485	485	485
97	490	490	490	490
98	495	495	495	495
99	500	500	500	500
100	505	505	505	505

Conclusions

- MIP model determines the number of donors and patients of a district allocated to blood facilities, but also the optimization of blood units allocation to BCs based on the consumption.
- It can support strategic/tactical decisions, because it is able to assign donors and patients who need of blood to the "right" facilities; able to assign blood units to BCs; determine how capacity should be increased to accommodate any increase in demand/supply, as possibility, forecast staff to be hired, trained, amount of equipment needed.



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Submissão #13

Analysing the export potentials of the Portuguese footwear industry by Data Envelopment Analysis

Dimitrios Sotiros, Maria Silva, Vasco Rodrigues

Exports are widely believed to play a central role in economic development and firms' profitability, particularly in countries with small domestic markets. With that aim, governments and firms spend considerable resources on international promotion. Identifying the markets with the greatest potential for export growth is therefore crucial for an efficient allocation of public and private resources. In this paper, we propose a Data Envelopment Analysis framework to identify trading potentials with existing trading partner countries within an industry. To illustrate its applicability, we use data from the Portuguese footwear industry. Specifically, among the countries that currently import Portuguese footwear, we aim to identify those that have the greatest potential for increasing their imports from Portuguese footwear in terms of revenue. We further decompose this potential into price and quantity changes to provide strategic directions to the Portuguese footwear industry. For the analysis, we use panel data of 64 countries analyzed over the years 2011-2018. The results reveal that higher potentials lie among the countries of the European Economic Area. Overall, these potentials may be achieved through different price-quantity strategies.

Keywords: Trading and exports, Data Envelopment analysis, Export performance

Analyzing the export potentials of the Portuguese footwear industry with Data Envelopment Analysis

D. Sotiros, M. Conceição Silva, V. Rodrigues

ANALYTICS FOR A BETTER WORLD

What do we want to know

1. Can Portuguese footwear industry increase its exports to other countries? What countries should it bet on?
2. Which should be the aimed revenue and should it be achieved by increasing prices, by increasing quantity or some mix of both?

How do we get to the answers?

DEA revenue model of Tone 2002

$$\max_{\lambda, V_o} \theta_{rv}^* V_o$$

s. t.

$$X\lambda \leq X_o$$

$$V\lambda \geq V_o$$

$$e_n \lambda = 1$$

$$\lambda, V_o \geq 0$$

Any pair of $(\bar{\theta}_{rp}, \bar{\theta}_{rq})$ such that $\bar{\theta}_{rp} \bar{\theta}_{rq} = \theta_{rv}^*$ will provide the optimal revenue.

setting $d_{pr0} = |1 - \theta_{pr0}|$ and $d_{yr0} = |1 - \theta_{yr0}|$,

Decomposing revenue targets into quantity and price changes

$$\min_{\theta_{rp}, \theta_{rq}, d_{pr0}, d_{yr0}} \theta_{rp} \theta_{rq} + d_{pr0} + d_{yr0}$$

s. t.

$$P_k = \theta_{rp} P_k$$

$$e_k = 1$$

$$Y_j = \theta_{rq} Y_j$$

$$d_{pr0} = 1$$

$$k \leq M^*$$

$$j \leq N^*$$

$$\theta_{rp} \theta_{rq} = \theta_{rv}^*$$

$$-\theta_{rp} d_{pr0} - d_{yr0} \leq -e_1^*$$

$$\theta_{rp} d_{pr0} - d_{yr0} \leq e_1^*$$

$$-d_{pr0} - d_{yr0} \leq -e_2^*$$

$$d_{pr0} - d_{yr0} \leq e_2^*$$

$$\theta_{rp}, \theta_{rq}, d_{pr0}, d_{yr0} \geq 0$$

$$e_1, e_2 \geq 0$$

Which sort of data and variables do we use?

Inputs	Outputs	Group	N	Probability (kno)	GDP (million USD)	World imports Rubber & plastic (million USD)	World imports Leather (million USD)	World imports Textile (million USD)	Portuguese imports Rubber and Leather (million USD)	Portuguese imports Textile (million USD)	Portuguese exports (million USD)
Proximity	Total value of imports of Plastic & Rubber footwear from Portugal	EEA-NPL	230	16942.08	623.3	383.02	958.81	433.10	2.70	106.05	3.56
	Total value of imports of Leather footwear from Portugal	NEEA-NPL	242	12074.39	1713.6	519.97	880.24	474.70	0.50	20.83	0.789
	Total value of imports of Plastic & Rubber footwear from the whole world	NEEA-NPL	30	16508.15	4.4	2.6	3.84	0.80	0.12	0.35	0.05
	Total value of imports of Textile footwear from Portugal	total	104	14454.98	1107.5	424.42	819.26	424.71	1.48	58.42	2.01
	Total value of imports of Leather footwear from the whole world										
	Total value of imports of Textile footwear from the whole world										
	EEA (leather variables)										
	PL (leather variable)										

Category	Description	Number of entries	Assessed with
(EEA-NPL)	EEA Countries whose spoken language is not Portuguese	230	(NEEA-NPL)
(NEEA-PL)	Non-EEA Countries whose spoken language is Portuguese	32	(NEEA-NPL)
(NEEA-NPL)	Non-EEA Countries whose spoken language is not Portuguese	242	-

2011-2018 data for 63 countries

What are the answers?

1. There is a large potential to increase Portuguese export revenue – mainly to EEA countries (Italy, UK, Belgium, Austria, Poland and France are among the ones with bigger potential within EEA countries and in 2018). For NEEA countries the ones with higher potential are Hong Kong U. Arab Emirates and Rep. Korea. Portuguese speaking countries have a negligible potential
2. Different strategies are proposed to achieve they revenue potential. For leather shoes for example, in some cases prices should decrease and quantities increase (Italy), in other prices should increase and quantities too (UK).

Submissão #14

Limites aos custos num modelo de Joint Replenishment Problem com itens sujeitos a obsolescência

Ricardo Afonso, Pedro Godinho, João Paulo Costa

Uma família de diferentes tipos de itens a encomendar pode ser constituída, entre outras razões, por os itens terem um fornecedor comum, serem entregues no mesmo meio de transporte ou serem produzidos na mesma unidade fabril. O Joint Replenishment Problem (JRP) debruça-se sobre a problemática de coordenação de encomendas com o objetivo de minimizar o custo total, composto por custos de encomendar e custos de posse, garantindo a satisfação da procura. A complexidade deste problema aumenta quando os itens estão sujeitos a processos de obsolescência. Isto decorre do facto de os itens poderem sofrer uma queda abrupta da procura por deixarem de ser necessários, devido ao rápido avanço da tecnologia, ficarem fora de moda, ou deixarem de ser economicamente viáveis, por exemplo. A presente comunicação considera uma extensão do JRP onde os itens podem repentinamente tornar-se obsoletos. A procura é assumida como constante e os tempos de vida dos itens seguem distribuições exponenciais negativas. Pretende-se, assim, otimizar o custo total atualizado esperado. Além da apresentação do modelo, abordam-se ainda algumas propriedades que podem conduzir ao desenvolvimento de aproximações para a obtenção de soluções de forma mais eficiente, tais como a definição de limites inferiores e superiores ao custo total.

Palavras chave: Gestão de stocks, Joint Replenishment Problem, Obsolescência

LIMITES AOS CUSTOS NUM MODELO DE JOINT REPLENISHMENT PROBLEM COM ITENS SUJEITOS A OBSOLESCÊNCIA

Ricardo Afonso, Universidade de Coimbra, CeBER, Faculdade de Economia | Alice Lobo, S.A. | Pedro Godinho, Universidade de Coimbra, CeBER, Faculdade de Economia | João Paulo Costa, Universidade de Coimbra, CeBER, Faculdade de Economia

Joint Replenishment Problem
Aquisição de N itens diferentes a um fornecedor, tendo em conta:
Custo fixo de emissão de encomenda (A)
Custo fixo por tipo de item i incluído na encomenda (a_i)
Custo unitário de aquisição dos diferentes tipos de itens (c_i)
Custo de posse unitário por tipo de item i por unidade de tempo (h_i)

Objetivo: minimizar o valor esperado do custo total atualizado

Variáveis de decisão:
O período (ciclo base) entre encomendas (T)
O número de ciclos base entre encomendas de cada tipo de item i , isto é, k_i para $i = 1, \dots, N$, tal que $T_i = k_i T$ e $k_i \in \mathbb{N}$

Itens sujeitos a processos de obsolescência repentina
Procura colapsa quando os itens deixam de ser necessários para os produtos ou sistemas para os quais foram adquiridos (Afonso et al., 2022)

Pressupostos
O tempo de vida dos itens é estocástico, seguindo uma distribuição exponencial negativa. Cada tipo de item i tem uma taxa de obsolescência θ_i
A procura por unidade de tempo é constante
Os custos incorridos são atualizados de acordo com uma taxa de desconto δ
Não são permitidas ruturas de stock
Não há descontos de quantidade
Os custos de posse são proporcionais à quantidade em stock
As entregas são instantâneas e o lead time é nulo

Formulação
A determinação do valor esperado do custo total atualizado tem em conta quer a possibilidade de a obsolescência ocorrer durante o ciclo T quer a de ocorrer após o ciclo T .

Custos incorridos durante o ciclo base T
 $w_0 = C_0 + C_a + C_h$
em que
 $C_0 = A + \sum_{i=1}^N a_i$ ← custos fixos de encomenda
 $C_a = \sum_{i=1}^N c_i D_i k_i T$ ← custos de aquisição
 $C_h = \sum_{i=1}^N h_i \theta_i \left(\frac{\theta_i k_i T}{\delta + \theta_i} + \frac{\theta_i (e^{-(\delta + \theta_i) k_i T} - 1)}{(\delta + \theta_i)^2} \right)$ ← custos de posse

Custos incorridos após o ciclo base T
Após o ciclo base T é necessário considerar todas as combinações possíveis em que pelo menos um dos tipos de itens não se torna obsoleto. Consequentemente, há que considerar os casos em que apenas um dos tipos de itens sobrevive, os casos em que apenas dois tipos de itens sobrevivem, e assim sucessivamente, até ao último caso em que todos os tipos de itens sobrevivem.

Os custos incorridos após o ciclo base T em que m ($1 < m <= N$) tipos de itens sobrevivem são expressos por:

Subconjunto com m tipos de itens: $\sum_{i_1, \dots, i_m \in S} E[V(S, T, (k_{i_1}, \dots, k_{i_m}))] e^{-\delta T} [1 - e^{-\theta_{i_1} T}] \dots [1 - e^{-\theta_{i_m} T}]$

Conjunto dos N tipos de itens: $E[V(S, T, (k_1, \dots, k_N))] e^{-\delta T} [1 - e^{-\theta_1 T}] \dots [1 - e^{-\theta_N T}]$

Valor ótimo da custo esperada quando os tipos de itens do subconjunto S não sobrevivem ao ciclo base T : w_m

Probabilidade dos m tipos de itens pertencentes ao subconjunto S não sobreviverem ao ciclo base T : $P(S)$

Probabilidade dos $N - m$ tipos de itens pertencentes ao subconjunto S^c não sobreviverem ao ciclo base T : $1 - P(S)$

Objetivo do modelo
$$\min_{T, k_i \in \mathbb{N}} E[V(S, T, (k_1, \dots, k_N))] = \frac{w_0 + e^{-\delta T} E\left[\sum_{i=1}^{N-1} w_i\right]}{1 - e^{-(\delta + \theta_1 k_1 + \dots + \theta_N k_N)T}}$$

Determinação da solução
Procedimento iterativo e recursivo para determinar w_m . Durante a primeira iteração otimizam-se os casos em que apenas um tipo de item sobrevive ao ciclo base T . Na segunda iteração, os valores da primeira iteração são utilizados para otimizar os casos em que dois tipos de itens sobrevivem. O procedimento continua até à iteração N em que o valor ótimo $E[V(S, T, (k_1, \dots, k_N))]$ é determinado.

Exemplo para $N = 2$:
$$\min_{T, k_1, k_2 \in \mathbb{N}} E[V(S, T, (k_1, k_2))] = \frac{w_0 + \sum_{i=1}^2 \sum_{j=1}^2 E[V((i, j), T, (k_i, k_j))] [1 - e^{-(\delta + \theta_{i,j})T} (1 - e^{-\theta_i k_i T})]}{1 - e^{-(\delta + \theta_1 k_1 + \theta_2 k_2)T}}$$

Input para determinar $E[V(S, T, (k_1, k_2))]$

Resultados

Risco obsolescência	Poupança	T	Quantidade
↘	↘	↘	↘
δ	Poupança	T	Quantidade
↗	↗	↗	↗

Limites para simplificação / soluções aproximadas
Verifica-se que $\lim_{N \rightarrow \infty} w_i = 0$, dado que a componente $e^{-\theta_i k_i T} [1 - e^{-\theta_i k_i T}] \prod_{j=1}^N (1 - e^{-\theta_j k_j T})$ é constituída pelo produto de N termos menores do que 1.

Limite inferior
Considerar apenas os valores esperados dos custos atualizados relativos ao ciclo base inicial T e os custos esperados dos demais ciclos em que apenas um dos N tipos de itens sobrevive, isto é,
$$LB = \frac{w_0 + e^{-\delta T} \sum_{i=1}^N E[V((i, 0), T, (k_i, 0))] e^{-\delta T} \prod_{j=1}^N (1 - e^{-\theta_j k_j T})}{(1 - e^{-(\delta + \theta_1 k_1 + \dots + \theta_N k_N)T})} = \frac{w_0 + e^{-\delta T} w_1}{1 - e^{-(\delta + \theta_1 k_1 + \dots + \theta_N k_N)T}}$$

Limite superior
Partindo do princípio que a reposição coordenada é melhor que a independente, considerar os custos atualizados esperados dos N tipos de itens assumindo que são encomendados independentemente com $k_i = 1, \forall i$, isto é,
$$UB = \sum_{i=1}^N E[V((i, 0), T, (1, 0))]$$

Logo, $LB \leq E[V(S, T, (k_1, \dots, k_N))] \leq UB$

Resultados de aplicação dos limites
Resultados obtidos com os limites propostos para cenários envolvendo 3 produtos:

#	LB	OPT	UB	(OPT-LB)/OPT	(UB-OPT)/OPT
1	\$ 3.066,07	\$ 3.526,12	\$ 4.815,50	30%	36%
2	\$ 3.497,10	\$ 4.492,21	\$ 7.664,34	36%	59%
3	\$ 1.508,02	\$ 3.377,05	\$ 3.905,05	58%	9%
4	\$ 1.111,41	\$ 2.403,50	\$ 2.420,15	50%	13%
5	\$ 12.086,52	\$ 21.877,53	\$ 25.248,27	45%	15%
6	\$ 1.753,83	\$ 1.778,71	\$ 2.022,52	34%	13%
7	\$ 1.851,02	\$ 4.073,98	\$ 8.317,83	37%	37%
8	\$ 1.077,54	\$ 4.485,22	\$ 4.348,80	40%	37%
9	\$ 1.086,14	\$ 3.914,75	\$ 3.513,24	43%	26%
10	\$ 8.357,05	\$ 15.803,21	\$ 18.948,36	47%	20%
11	\$ 1.629,87	\$ 1.980,75	\$ 2.638,07	44%	23%
12	\$ 3.875,80	\$ 19.089,51	\$ 22.293,78	48%	17%

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Submissão #15

Weighted proximity search

Filipe Rodrigues, Agostinho Agra, Lars Magnus Hvattum, Cristina Requejo


Proximity search is an iterative method to solve complex mathematical programming problems. At each iteration, the objective function of the problem at hand is replaced by the Hamming distance function to a given solution, and a cutoff constraint is added to impose that any new obtained solution improves the objective function value. A mixed integer programming solver is used to find a feasible solution to this modified problem, yielding an improved solution to the original problem. We introduce the concept of weighted Hamming distance that allows to design a new method called weighted proximity search. In this new distance function, low weights are associated with the variables whose value in the current solution is promising to change in order to find an improved solution, while high weights are assigned to variables that are expected to remain unchanged. The weights help to distinguish between alternative solutions in the neighborhood of the current solution, and provide guidance to the solver when trying to locate an improved solution. Several strategies to determine weights are presented. The proposed weighted proximity search is compared with the classic proximity search on instances from three optimization problems leading to very promising results.

Keywords: Mixed integer programming, Matheuristic, Local search



Weighted Proximity Search

Filipe Rodrigues, Agostinho Agra, Lars Magnus Hvattum, Cristina Requejo



Proximity search

Proximity search (PS) is an iterative method proposed in [1] to solve complex optimization problems involving binary variables. At each iteration, the objective function is replaced by the Hamming distance function (HDF) to a given solution, and a cutoff constraint is added to impose that any new obtained solution improves the objective function value. Formally, the original problem and the modified problem can be formulated as follows:

$$\begin{aligned} \min f(x, y) \\ \text{s.t. } g_i(x, y) \leq 0, \quad i \in I, \\ x \in \{0, 1\}^n, \\ y \in \mathbb{R}^p \times \mathbb{Z}^q \end{aligned} \quad \Leftrightarrow \quad \begin{aligned} \min \Delta(x, \bar{x}) \\ \text{s.t. } f(x, y) \leq f(\bar{x}, \bar{y}) - \theta, \\ g_i(x, y) \leq 0, \quad i \in I, \\ x \in \{0, 1\}^n, \\ y \in \mathbb{R}^p \times \mathbb{Z}^q \end{aligned}$$

where x is a set of structural binary variables, y is the set of the remaining variables, (\bar{x}, \bar{y}) is a feasible solution, θ is a predefined cut-off tolerance, and $\Delta(x, \bar{x})$ is the HDF defined as

$$\Delta(x, \bar{x}) = \sum_{j \in N | \bar{x}_j = 0} x_j + \sum_{j \in N | \bar{x}_j = 1} (1 - x_j)$$

The weighted proximity search

The PS aims to improve a given feasible solution (\bar{x}, \bar{y}) by exploring its neighborhood, where the closest neighbors are those that minimize the HDF. However, since all variables x_j have coefficient one in the HDF, no additional information is provided to the MIP solver regarding the quality of the current value of the variables. To guide the PS, we introduce a new distance function, called weighted HDF, defined as

$$\Delta_w(x, \bar{x}) = \sum_{j \in N | \bar{x}_j = 0} w_j x_j + \sum_{j \in N | \bar{x}_j = 1} w_j (1 - x_j)$$

where a weight w_j is associated with each binary variable x_j . The weighted HDF intends to inform the MIP solver about which variables are more promising to change for finding an improved solution. Hence, higher weights should be assigned to the variables whose change is less promising, while lower weights should be associated with the variables whose change is more promising.

Define the weights

To define the weights, we propose both static and dynamic strategies, see [2] for more details.

Static strategies:

- ✓ **Consistent variables identification** – several feasible solutions are initially obtained, and the weight of each variable is defined according to the number of times such a variable takes value one and zero in the obtained solutions.
- ✓ **Linear relaxation proximity** – the weight of each variable is defined based on the distance of the current value of such a variable to the value it takes in the LP-relaxation solution.
- ✓ **Linear relaxation loss** – the weight of each variable is computed taking into account the LP-relaxation value and the value obtained by solving the LP-relaxation problem with the value of such a variable fixed to its current value.

Dynamic weights:

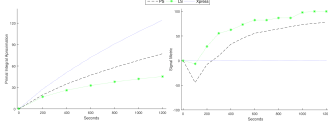
- ✓ **Recent change indicator** – the weight of each variable is determined considering if such a variable has changed its value in the previous iteration or not.
- ✓ **Weighted frequency** – the weight of each variable is calculated based on the relation between all previous values assumed by such a variable and the value of the corresponding solutions.
- ✓ **Loss/saving (LS)** – the weight of each variable is computed according to the loss/gain in the objective function caused by flipping the current value of such a variable while keeping the remaining variables fixed to their current value.

Weights discretization

The weights defined may assume a wide range of values, which may be undesirable. Hence, after computing the weights, we mapped them into a three-value system such that $w_j \in \{1, 5, 10\}$.

Computational results

Among all the strategies used for defining weights, the LS strategy revealed to be the best one. Here, we only present the results for the weighted PS combined with this strategy for the p-medium instances, however, we perform experiments in other two sets of instances: set covering problem and stochastic lot-sizing. We compare the proposed weighted PS against the classic PS and Xpress. The comparison is made using two quality measures: primal integral approximation and signal metric. The first measure is related to the gap between the obtained solutions and the best-known feasible solutions, and therefore, lower values are better. The signal metric is related to the percentage of times the solution of the PS and weighted PS is better than the one obtained by Xpress, and therefore, higher values are better.



Conclusions

The LS strategy proved to be the best one for defining weights. The proposed weighted PS combined with the LS strategy clearly outperforms both the classic PS and the Xpress (run by 1200 seconds), which makes this new method very promising to solve complex optimization problems with binary variables.

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Submissão #17



Melhoria da equidade no planeamento de ambulâncias a nível tático e operacional: um modelo de otimização orientado por dados.

Paulo Abreu, Daniel Santos, Ana Barbosa-Póvoa

O planeamento de ambulâncias envolve um conjunto de problemas de planeamento interrelacionados abordados a nível tático e operacional de forma independente, onde se incluem problemas de localização e de realocação das ambulâncias. Estudos recentes têm estudado a incorporação de equidade no primeiro problema onde as decisões são tomadas num horizonte de planeamento de médio prazo; contudo, estes estudos demonstram a existência de um desequilíbrio em termos de equidade e eficiência. Por outro lado, o segundo trata de decisões que são tomadas a curto prazo e centra-se na atualização da correspondência entre a oferta e a procura. Reconhecendo as características dos problemas e o facto da equidade ser um objetivo emergente a ser alcançado, propõe-se um novo modelo dinâmico de otimização para lidar com ambos os problemas em simultâneo, visando ultrapassar a questão da ineficiência. Para além do novo modelo, propõe-se uma abordagem que explora a equidade a partir de diferentes perspetivas, nomeadamente vertical e horizontal. Resultados computacionais mostram que tal abordagem contribui para melhorar a equidade de ambos os lados, pessoal e população, e demonstra que as realocações resultam num benefício que não é linear, explicando a resistência dos decisores em executá-las na prática.

Palavras chave: Serviços de Emergência Médica, Equidade, Problema de Localização das Ambulâncias, Problema de Realocação das Ambulâncias, Programação Linear Inteira Mista



#17 Improving equity in ambulance planning at the tactical and operational levels: a data-driven optimization model.

Paulo Abreu^a, Daniel Santos^a, Ana Paula Barbosa-Póvoa^a
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Highlights

- Incorporates equity in ambulance planning in view of staff and population.
- Allows decision-makers to explore lessons learned from their systems.
- Approaches two problems simultaneously to overcome inefficiency.
- Demonstrates that relocating ambulances does not result in a linear benefit.
- Analyzes value added from different perspectives of equity in resource allocation.

Objective

Study new equity approaches for ambulance planning at the tactical and operational levels.

Motivation

The models available on the literature assumes that planners are willing to accept the number of relocations defined by the models, and resource allocation must be from a single equity perspective. (Arlinghieri et al., 2017).

The results of McLay and Mayorga (2010) appear that locating ambulances to maximize the response time threshold, i.e. ensuring similar response times to all the users, is an implicit way to incorporate equity resulting in a more equitable system.

Jagtenberg and Mason (2020) and Jagtenberg et al. (2021) explored the Bernoulli-Nash measure of social welfare to propose time sharing between bases in order to make better use of idle vehicles, however, it lacks a criterion to establish such collaboration between bases.

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Model

Continuous variables

ω_{bt}^i : Time share that vehicles of type i housed at base b should dedicate serving demand node d , during time period t and working shift s .

ω_{bt}^j : Equity perspective explored for vehicles of type j housed at base b

Integer variables

a_{bt}^i : Quantity of active vehicles of type i housed at base b during time period t and working shift s .

s_t^i : Quantity of stand-by vehicles of type i housed at base b during time period t

R_{bt}^i : Quantity of vehicles of type i removed from base b during time period t

R_{bt}^{i+} : Quantity of vehicles of type i added to base b during time period t

Coverage-equity objective function

$$\max \sum_{t \in T} \sum_{b \in B} \sum_{i \in I} \sum_{d \in D} \left(\omega_{bt}^i \cdot (a_{bt}^i \cdot \lambda_{bd} + \omega_{bt}^j \cdot (a_{bt}^j \cdot \lambda_{bd} - \frac{1}{\sqrt{1 - \beta_{bd}^i}} \cdot \lambda_{bd} \cdot \omega_{bt}^i)) \right)$$

Equity constraints

$$\omega_{bt}^i = \frac{D_{bd} \cdot \lambda_{bd}}{\sum_{i \in I} D_{bd} \cdot \lambda_{bd}} \cdot \left(\frac{D_{bd} \cdot \lambda_{bd}}{\sum_{i \in I} D_{bd} \cdot \lambda_{bd}} \cdot \omega_{bt}^i + \sum_{j \in I, j \neq i} \omega_{bt}^j \cdot \lambda_{bd} \cdot \lambda_{bd} \cdot \omega_{bt}^j \right) \cdot \forall d \in D, b \in B, i \in I, t \in T, s \in S$$

Proposed scenarios to explore different equity perspectives

ω_{bt}^i	Equity perspectives	Scenarios
0.0	Horizontal equity	Fleet with a small number of vehicles of the same type, or situations in which vehicles are housed at bases that meet demand nodes more susceptible to Black Swan events.
0.5	Balanced	Fleet with a large number of vehicles of the same type, or situations in which vehicles are housed at bases that meet demand nodes more susceptible to Grey Swan events.
1.0	Vertical equity	Bases that meet demand nodes more susceptible to White Swan events.

Case study

Locations of ambulance bases in Lisbon and their synergy graph

System characteristics:

- 3 working shifts of 8h/day
- Two priority levels: P1 = Emergent situations; P2 = Urgent situations
- Does not explore relocations

Resources:

- 20 bases
- AMBSIV vehicles: 1(M), 1(E), 1(N)
- VMER vehicles: 3(M), 3(E), 3(N)
- AEM vehicles: 14(M), 13(E), 7(N)

Dispatch combinations:

Priority level	Vehicle types
P1	AEM + VMER or AMBSIV
P2	VMER + AMBSIV
P3	AEM or AMBSIV

Results

Sensitivity analysis of parameters ω_{bt}^i

- The results indicate that the optimal solution imposes the whole system under the vertical equity.
- Allowing one relocation for AEM and AMBSIV vehicles (AEM=1, VMER=0, AMBSIV=1) during each time period increases the coverage-equity measure in +4.2% when compared with a static allocation (AEM=0, VMER=0, AMBSIV=0).

Sensitivity analysis of parameters λ_{bd} and ω_{bt}^i

- The worst coverage-equity measure is observed imposing the horizontal equity to the whole system.
- Additional relocations for AEM vehicles provide a marginal increase lower than 1.0% in the coverage-equity measure.
- The balanced perspective alone provides an increase of +0.8%, which is surpassed by the fourth hypothesis based on system characteristics with an increase of +5.8%.

Conclusions and future work


- The results help to explain why decision-makers are unwilling to adopt planning tools that explore relocations and approach equity only from the horizontal perspective.
- The lack of efficiency highlighted in the literature for models that explore equity in ambulance planning is overcome by addressing the Ambulance Location and Relocation Problems simultaneously.
- Relocations help balance the workload by exploring equity in view of staff, while different equity perspectives allow planners to explore equity in view of


Future work includes:

- Simulation of the solutions to measure the improvements in terms of response times and exploration of other case studies.

Acknowledgements

We thank the Portuguese EMS provider (INEM) for all the clarifications and for providing the data. This work was supported by the Portuguese National Funding (FCT) (DS/PA/Al/0044/2016).





Submissão #19

A resectorization of fire brigades in the north of Portugal

Maria Margarida Lima, Elif Goksu Ozturk, Filipe S. de Sousa, Cristina Lopes, Cristina Teles, Ana Maria Rodrigues, Ana Catarina Nunes, José Soeiro Ferreira

Sectorization can be regarded as a division of a territory into smaller regions to deal with a complex problem involving multiple-criteria. Resectorization intends to achieve another sectorization, according to some new conditions but avoiding substantial changes. An example of this can be the distribution of geographical areas by fire brigades. In Portugal, fire brigades must protect and rescue the population in the areas surrounding their fire stations. So we will use the current sectorization, the geographic and population characteristics of the areas and the fire brigades' response capacity to provide an optimized resectorization, in order to decrease rescue time. To achieve that, we will use a decision support system using different optimization methods, such as Non dominated Sorting Genetic Algorithm (NSGA II), which provides an effective sectorization concerning compactness and equilibrium criteria. This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-031671.

Keywords: Sectorization, Resectorization, Fire Brigades, Multiple-criteria

A resectorization of fire brigades in the north of Portugal

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 Ana Maria Rodrigues^{1,2}, Ana Catarina Nunes^{4,6} and José Soeiro Ferreira^{2,5}
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Is the sectorization of Portuguese fire brigades already optimised?

Using the current sectorization, the geographic and population characteristics and the fire brigades' response capacity we provide an optimised resectorization, to decrease rescue time.

Sectorization: division of a region into smaller regions.

Resectorization: to achieve another division of a region according to some new conditions but avoiding substantial changes, maintaining some degree of similarity between the solutions.

Capacity of each fire brigade (c_i):

$$c_i = 0.5g_1A_i + 0.3g_2V_i + 0.2E_i$$

A_i - number of ambulances in brigade i
 V_i - number of fighting vehicles (forest and industrial) in brigade i
 E_i - adimensional number of firefighters in brigade i
 g_1, g_2 - constant parameters

Demand of each subregion (s_j):

$$s_j = 0.6P_j + 0.4Q_j$$

P_j - adimensional population in subregion j
 Q_j - adimensional area of subregion j

Sectors must be:

- Balanced

Minimise the standard deviation of the occupancy percentage of fire brigade i in order to obtain balanced sectors

$$\min \sqrt{\frac{\sum_{i=1}^M (k_i - \bar{k})^2}{N}}$$

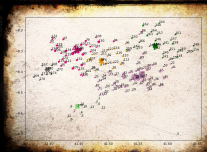
where $k_i = \frac{c_i}{s_i}$ is the percentage of used capacity of fire brigade $i \in \{1, \dots, M\}$, \bar{k} is the average of k_i and s_j is the demand of the subregion j , if j is assigned to the fire brigade i and zero otherwise.

- Compact


Minimise the distance between fire brigades and subregions, weighted by the demand of each subregion, in order to obtain compact sectors

$$\min \sum_{i=1}^M \sum_{j=1}^N d_{ij} s_j$$

where d_{ij} is the distance between brigade $i \in \{1, \dots, M\}$ and subregion $j \in \{1, \dots, N\}$.



Current sectorization has 0.284 of equilibrium and 0.035 of compactness








The optimal resectorization has 0.053 of equilibrium and 0.037 of compactness with a similarity of 70.2%

Contributions:

OPTIMISE SECTORIZATION AND MINIMISE RESCUE TIME

Work developed by the team of FCT Project StoSS, with precious collaboration of fire brigades in the north of Portugal region.

This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-031671.

Submissão #20

Allocation Scheduling with Resource Synchronization and Uncertain Surgery Durations: A Two-Stage Stochastic Programming Approach

Steffen Heider, Daniel Santos, Inês Marques, Jens Brunner

Scheduling surgeries in a hospital is a challenging task for operating theater managers and surgeons. Many resources, e.g., rooms, surgeons, nurses, anesthetists as well as machines need to be scheduled simultaneously and need to be available at defined times of each surgery. Uncertain time of surgical sub procedures only increases the complexity. In practice, this problem is usually split in smaller subproblems where specialties are assigned to rooms and necessary resources are attached to a room, allowing specialties to schedule and sequence their surgeries independently. We present a two-stage stochastic programming model using a Benders decomposition approach to minimize idle time, overtime, and cancelled surgeries. We determine the surgery sequence and starting time for each resource including breaks and resource dependent available times, allowing for an individual patient sequence for each resource. We show that we can solve small and medium size instances to optimality.

Keywords: Elective Patient Scheduling, Synchronizaton, Uncertainty, Stochastic Programming, Benders Decomposition

Allocation Scheduling with Resource Synchronization and Uncertain Surgery Durations: A Two-Stage Stochastic Programming Approach

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Example

Introduction

Problem:

- Allocation scheduling, i.e., determining the sequence for surgeries in a particular day, which is an operational decision of Operating Room Planning and Scheduling.

Main contributions:

- Multi-resources with individual work hours and break times;
- Resource-dependent surgical times with synchronization;
- Stochastic surgery durations + Benders decomposition.

Goals:

- Minimize expected overtime, idle time and cancellations;
- Take advantage of resource-dependent surgical times.

Notation

<p>Sets and indices</p> <p>$g \in G$: Resource groups</p> <p>$r \in R$: Resources</p> <p>$w \in W$: Patients</p> <p>$e \in E$: Scenarios</p> <p>$E^s \subset E$: Scenarios in the subproblem</p> <p>$E^m \subset E$: Scenarios in the master problem</p> <p>$R_g \subset R$: Resources of resource group g</p> <p>$T \subset R$: Operating rooms</p>	<p>Parameters (cont.)</p> <p>B_r: Latest break time of resource r</p> <p>O_r: Maximum overtime of resource r</p> <p>α_r: Overtime penalization of resource r</p> <p>β_r: Idle time penalization of resource r</p> <p>θ_r: Cancelling penalization of patient r</p> <p>ω_e: Weight of scenario e</p> <p>Decision Variables</p> <p>x_{ij}^r: 1, if resource r goes from patient/start node/break node i to patient/end node/break node j</p> <p>y_{ir}: 1, if patient i is scheduled with resource r</p> <p>z_i: 1, if patient i is scheduled</p> <p>o_r^e: Overtime of resource r in scenario e</p> <p>l_r^e: Idle time of resource r in scenario e</p> <p>s_{ij}^e: Start time of resource r for surgery/break i in scenario e</p>
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Objective Function

Minimize: $\sum_{i \in W} \theta_i (1 - x_i) + \sum_{e \in E^m} \eta_e \sum_{r \in R} (\alpha_r o_r^e + \beta_r l_r^e) + \sum_{e \in E^m/E^s} \eta_e \gamma_e$

Constraints

$y_{ir} = \sum_{j \in \{i, B_r\}} x_{ij}^r \quad \forall i \in W, r \in R$
 $\sum_{r \in R} y_{ir} = A_{ir} \quad \forall i \in W, g \in G$
 $\sum_{i \in \{i, B_r\}} x_{ij}^r - \sum_{i \in \{j, B_r\}} x_{ij}^r = 0 \quad \forall r \in \{W, E, B\}, r \in R$
 $\sum_{i \in \{i, B_r\}} x_{ij}^r = 1 \quad \forall r \in R$
 $\sum_{i \in \{i, B_r\}} x_{ij}^r = 1 \quad \forall i \in E^m, i \in W, r \in \{R, T\}, i \in T$
 $x_{ij}^r \leq y_{ir} + O_r - M(1 - y_{ir}) \quad \forall i \in E^m, i \in W, r \in \{R, T\}, i \in T$
 $x_{ij}^r \geq y_{ir} - O_r - M(1 - y_{ir}) \quad \forall i \in E^m, i \in W, r \in \{R, T\}, i \in T$
 $x_{ij}^r \leq z_i \quad \forall i \in E^m, j \in W, r \in R$
 $x_{ij}^r \leq z_i \quad \forall i \in E^m, j \in W, r \in R$
 $o_r^e + D_{ir} \leq s_{ij}^e + B_r - B_i \quad \forall i \in E^m, r \in R$
 $l_r^e + D_{ir} \leq s_{ij}^e - D_{ir} - \sum_{k \in E^m} \omega_k y_{ik} - M(1 - z_i) \quad \forall i \in E^m, r \in R$
 $l_r^e \leq O_r - s_{ij}^e - \sum_{k \in E^m} \omega_k y_{ik} - M(1 - z_i) \quad \forall i \in E^m, r \in R$

Benders optimality cuts
Benders feasibility cuts

$x_{ij}^r, y_{ir}, z_i \in \{0, 1\}$
 $o_r^e, l_r^e \geq 0$
 $s_{ij}^e \geq s_{ij}^e + A_r$

Preliminary results

- Individual resource sequencing allows to save time in most cases;
- Benders decomposition algorithm finds solutions with up to 10 patients and 100 scenarios within 1 hour;
- Difficulty in closing the optimality gap due to weak lower bounds.

Conclusions

- Surgery sequencing with uncertainty;
- Resource-dependent surgical times;
- Based on VRP with synchronization.

Next steps

- Improve the solution method.

Acknowledgements

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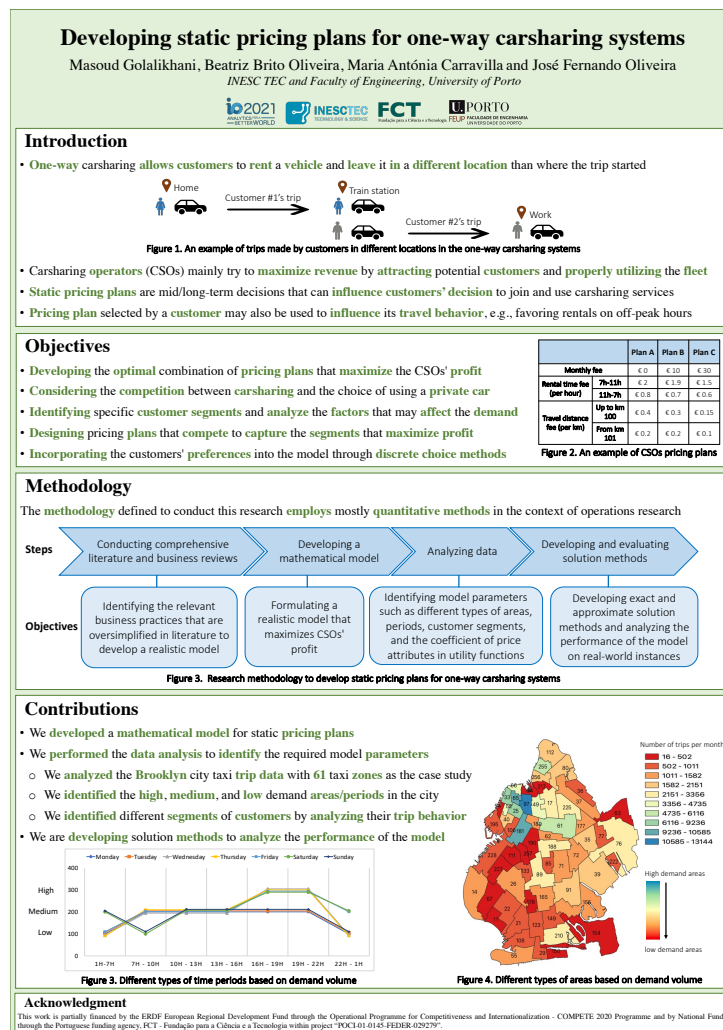
Submissão #21

Developing static pricing plans for one-way carsharing systems

Masoud Golalikhani, Beatriz Brito Oliveira, Maria Antónia Carravilla, José Fernando Oliveira

As an alternative to private cars, one-way carsharing systems allow customers to rent vehicles for a short period (e.g., minutes) and leave them in a different location than where the trip started. One of the main challenges of one-way carsharing operators (CSOs) is to maximize revenue by attracting potential customers and properly utilizing the fleet. In this regard, static pricing plans are mid/long-term decisions that influence customers' decision to join carsharing. The pricing plan selected by a customer may also be used to influence its travel behavior, e.g., favoring rentals on off-peak hours. Nevertheless, the literature often assumes a single-tariff plan for all customers (e.g., €1 per minute), while CSOs in the market offer several plans with different attributes (e.g., registration, travel distance, and rental time fees) to attract various customer segments. To fill this gap, we develop a model to design the optimal combination of pricing plans competing to capture representative segments of customers to maximize CSOs revenue, considering competition with the choice of using a private car. To this aim, we analyze customers' travel patterns and spatial-temporal factors that may affect the demand and identify specific customer segments whose preferences are incorporated in model through discrete choice methods.

Keywords: One-way carsharing, Pricing decisions, Customer segmentation



Submissão #22

Heuristics for the on-line three-dimensional packing problems


Sara Ali, António G. Ramos, Maria Antónia Carravilla, José Fernando Oliveira

The on-line three-dimensional packing problem is an NP-hard optimization problem in which items arrive sequentially over time, and at each step, the current item must be placed into containers immediately before the next item is revealed. This placement decision must be made under incomplete information about the numbers and sizes of upcoming items. On-line packing arises in many real-world problems, like robotic or automatic container loading in warehouse storage. Despite the numerous practical applications of on-line problems in real-world situations, most of the literature to date has focused on off-line problems where full knowledge about items is available beforehand. Moreover, in terms of solution approaches, the literature is quite sparse concerning heuristic methods that can be applied for solving on-line problems. Therefore, due to the crucial role of heuristic methods in finding effective solutions for real-world-sized problems in a reasonable amount of time, this study mainly focused on the development of on-line heuristic methods. The main contribution of this paper is to develop several unique on-line heuristics considering the major requirements that need to be satisfied in the on-line environments. Furthermore, we evaluate the performance of identified heuristics on a wide variety of on-line instances.

Keywords: Three-dimensional packing, On-line packing problem, Packing heuristics

Heuristics for the on-line three-dimensional packing problems

Sara Ali¹, António Galvão Ramos¹, Maria Antónia Carravilla² and José Fernando Oliveira³
¹INESC TEC and Faculty of Engineering, University of Porto, ²INESC TEC, and ³School of Engineering, Polytechnic Institute of Porto



Introduction

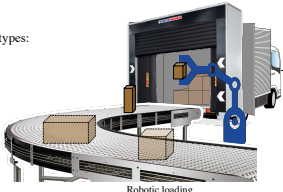
Three-Dimensional Packing Problem (3D-PP) can be classified into two main types:

Off-line 3D-PP

- Information about all **items available** beforehand
- Algorithm** can freely **choose any item** to pack into a bin

On-line 3D-PP

- Items arrive **one by one** and are **packed immediately** on arrival
- Algorithm** does not have **any information** about **upcoming items**
- On-line packing** has many real-world applications like **robotic loading**
- Very few studies** have addressed the **on-line 3D-PP**




Robotic loading

Objectives

To **develop on-line heuristics** for 3D-PP considering on-line requirements
 To **evaluate the performance of heuristics** on a wide variety of **instances**
 Since **solution approaches** for the **off-line 3D-PP** are **mainly based on heuristics**, and **literature is quite sparse** regarding **heuristic methods** for the **on-line 3D-PP**

On-line 3D-PP heuristic can involve four main components:

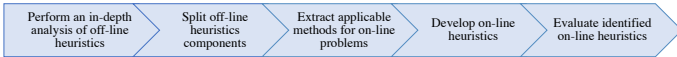
- Identifying** and **representing** potential free **spaces** inside the bins
- Selecting** the **suitable bin** with enough space for packing arrival item
- Prioritizing** the identified free **spaces** inside the selected bins
- Placing** the arrival item in the **selected space** based on a specific rule



Where and How to pack the arrival item

Methodology

To achieve the research objectives, we defined a five-phases research methodology

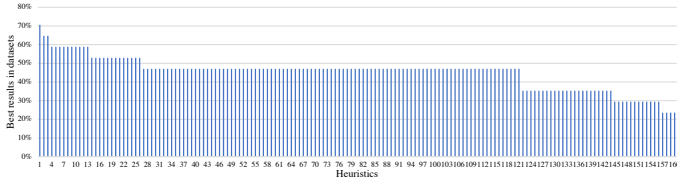


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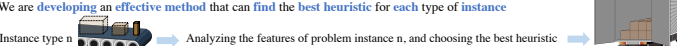
    graph LR
      A[Perform an in-depth analysis of off-line heuristics] --> B[Split off-line heuristics components]
      B --> C[Extract applicable methods for on-line problems]
      C --> D[Develop on-line heuristics]
      D --> E[Evaluate identified on-line heuristics]
    
```

Results

We developed **160 unique on-line heuristics**
 We evaluated the performance of 160 heuristics on 17 major classes of instances



None of the heuristics can provide good-quality results for all instances
 Performance of heuristics is related to the features of problem instances
 We are developing an effective method that can find the best heuristic for each type of instance



Instance type n → Analyzing the features of problem instance n, and choosing the best heuristic →

Acknowledgment

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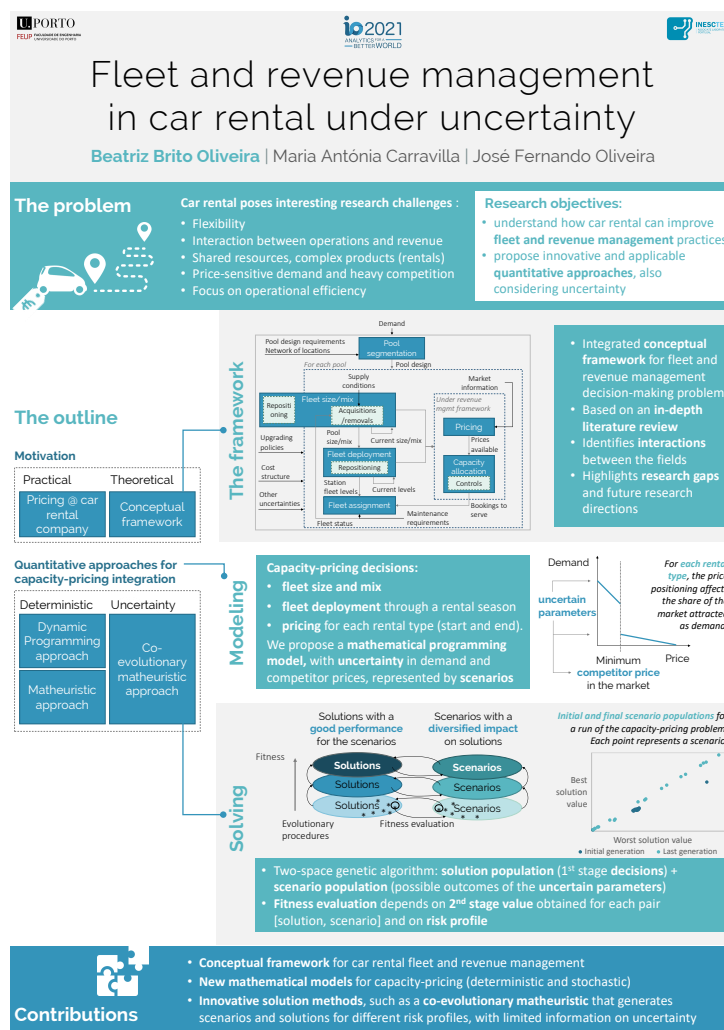
Submissão #23

Fleet and revenue management in car rental under uncertainty

Beatriz Brito Oliveira, Maria Antónia Carravilla, José Fernando Oliveira

Car rental systems face significant fleet management challenges. Additionally, their flexibility allows using pricing and other revenue management tools to influence demand. This flexibility is higher than in other traditional revenue management sectors, e.g. airlines, since it is easier to move and increase/decrease resources. This communication presents an overview of the work developed in this context, which filled a literature gap by structuring, modelling and solving the integration of fleet and revenue management problems in this business. Moreover, this work built the ground to extend the knowledge on integrating fleet and revenue management to other shared mobility applications. We studied the interactions between fleet and revenue management in car rental, proposing an integrated conceptual framework from which relevant future research directions stemmed. From there, we proposed models and solutions methods focusing on capacity-pricing problems, also considering uncertainty in demand and competitor prices. In this context, a significant number of uncertain parameters with unknown probability distributions can represent uncertainty. In such cases, we propose that metaheuristics, namely based on genetic algorithms, can generate relevant and complex scenarios. We developed an innovative approach based on a co-evolutionary metaheuristic, where solutions and scenarios are generated and evolve in parallel. (Resumo submetido no âmbito do Prémio APDIO / IO2021)

Keywords: Fleet management, Revenue management, Car rental, Optimization models, Metaheuristics



Submissão #24

An optimization approach for tactical collection and production planning in the blood supply chain

Maria Meneses, Ana Barbosa-Póvoa, Daniel Santos

Collection plays a critical role in the blood supply chain as blood is a limited resource that can only be obtained from donors. Also, it is the foundation to produce the necessary blood products. Given their perishability, production should closely mirror demand requirements to guarantee an adequate supply and avoid wastage. Such planning activities are subject to uncertainty, which adds complexity to the management of the blood supply chain. To deal with the stochastic environment whilst keeping the desired service level, it is of utmost importance to develop appropriate tools to address mid-term collection plans coupled with production balancing requirements that achieve some balance between shortages and wastage. To that end, this work presents an optimization model for collection and production of blood products at the tactical level, under supply and demand uncertainties. The proposed model considers an established blood supply chain with multiple facilities, which constrain the collection and production strategies by the limited personnel and resources capacity of the network. So, the model also optimizes the available resources. Besides, the donor pool available and respective allocation to different collection methods is addressed.

Keywords: Supply Chain Management, Optimization Modeling, Health Care



An optimization approach for tactical collection and production planning in the blood supply chain

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Introduction

The planning process is of the utmost importance when it comes to managing the blood supply chain, given the number of stages that must be carefully thought out in advance to guarantee the daily availability of blood products to satisfy demand. Blood supply chain management has been significantly addressed in the literature. However, there is a gap when it comes to define optimal collection and production strategies at a tactical level.

Problem



Collection: donors voluntarily go to bloodmobiles, temporary collection sites and blood centers where they donate blood (**SUPPLY**)
Distribution: donations should be shipped to their designated blood center
Production: donations are tested and fractionated into blood products.
Storage: products are stored until distributed to demand nodes (**DEMAND**)

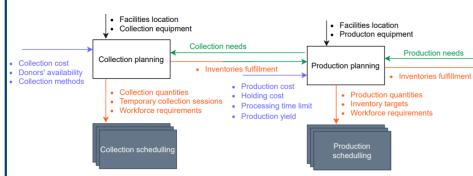
Planning a collection and production strategy involves defining the quantity of donations required of each blood type and collection method aligned with the production requirements. For the bloodmobiles and temporary fixed collection sites, it also involves defining the corresponding location for the collection session in each period considering resources limitations.

Objectives

- Develop an optimization model for collection and production of blood products at the tactical level, under supply and demand uncertainties.
- To test the decision-making model with a real Portuguese case study.
- To build an effective decision-making tool be used by the Portuguese blood services.

Optimization model

Objective function:
 Minimizing (1) Distance travelled, (2) Blood transshipment, (3) Set up costs, (4) Collection costs (5) Production costs and (6) Blood wastage.



Preliminary results

- Only a small instance was optimized in python
- A reduction in the overall costs, blood shortage and wastage in all stages of the blood supply chain was observed.

Future work

- Apply the model to a real case
- Deal with uncertainty in supply and demand
- Adopt a solution approach capable of solving such complex and high detailed model.

Acknowledgements

The authors gratefully acknowledge the support provided by FCT 2020.06549.BD and by LAItE/Blood- DSAIPA/AI/0033/2019



Submissão #25

Green Reverse Logistics: exploring the Vehicle Routing Problem with Pickups and Deliveries with environmental goals

Maria João Santos, Bruna Mota, Tânia Ramos, Ana Barbosa-Póvoa

The Vehicle Routing Problem with Divisible Deliveries and Pickups (VRPDDP) is under-explored in the literature, yet it has a wide application in practice in a reverse logistics context. The problem considers that each customer has both delivery and pickup demands and may be visited twice in the same or different routes. A restriction on the free capacity of the vehicles before starting the pickups to avoid load-shuffling problems may be considered. In this work, we explore the economic and the environmental impacts of the VRPDDP, with and without restrictions on the free capacity, and compares the savings achieved with splitting customers visits with the traditional Vehicle Routing Problem with Simultaneous Deliveries and Pickups (VRPSDP). The VRPDDP solutions are also characterized in terms of route shapes. A multi-objective approach based on the augmented ϵ -constraint method is applied to obtain and compare solutions minimizing costs and CO₂ emissions. The results demonstrate that the higher is the importance of CO₂ emissions in the objective function, the higher is the benefit of splitting customers. Moreover, the percentage savings of the VRPDDP are higher for instances with a random network than with a cluster network of customers, in comparison to the VRPSDP.

Keywords: Vehicle Routing Problem, reverse logistics, CO₂ emissions, ϵ -constraint



Green Reverse Logistics: exploring the Vehicle Routing Problem with Pickups and Deliveries

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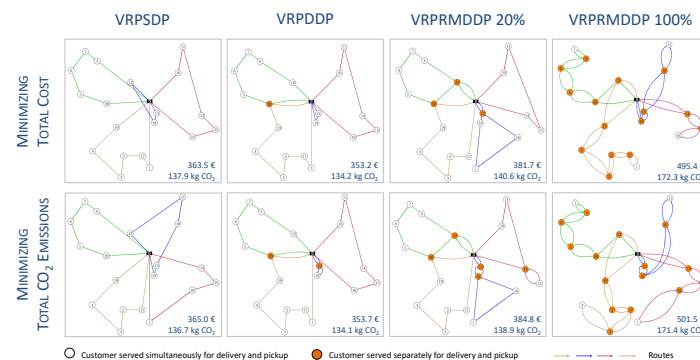
Introduction

The most common practice of reverse logistics in manufacturing industries is to deliver the customers their orders and, simultaneously, collect the returned items for recycling, remanufacturing or disposal. However, there can be an opportunity to save costs and CO₂ emissions if some delivery and pickup services occur separately. In some cases, it is even imposed a free capacity of about 20% to initiate the pickups to avoid the load-shuffling problem. In others, this free capacity may be of 100% if the delivery and pickup goods are not allowed to be in the same space to avoid cross-contamination.

Objectives

- To investigate the economic and environmental impacts of four different reverse logistics problems:
 - Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP)
 - Vehicle Routing Problem with Divisible Delivery and Pickup (VRPDDP)
 - Vehicle Routing Problem with Restricted Mix Divisible Delivery and Pickup, free space capacity of 20% (VRPRMDDP 20%)
 - Vehicle Routing Problem with Restricted Mix Divisible Delivery and Pickup, free space capacity of 100% (VRPRMDDP 100%)
- To evaluate the economic and environmental savings of splitting customers visits

Solutions – an example

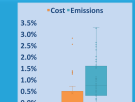


Conclusions

1. The majority of economic solutions for the VRPDDP and VRPRMDDP 20% are different than their respective environmental solutions.



2. Savings up to 2.8% in total costs and up to 3.3% in total CO₂ emissions can be achieved with splitting customers visits for delivery and pickup



Acknowledgements
The authors acknowledge the support provided by FCT and PORTUGAL2020 under the project PTDC/EGE-OGE/28071/2017, Lisboa-01.0145-Feder-28071.

Submissão #26

A Non-Convex Global Malmquist index to Compare the Performance of Water Services among Brazilian Macro-Regions

Ana Camanho, Marco Tourinho, Flávia Barbosa, Paulo Rosa Santos, Francisco Taveira Pinto

This paper proposes an innovative framework based on optimisation techniques that can support decision-making in water services. The proposed models estimate a Best-Practice frontier recurring to a 'Benefit-of-the-Doubt' formulation that enables benchmarking performance across decision-making units. We propose an innovative estimation of a pseudo-Malmquist index to compare the performance of groups. The framework's relevance is illustrated using data of the Brazilian water and sanitation regulator, collected at the municipality level for the year 2019. The groups compared correspond to three Brazilian macro-regions. The results obtained show that the Southeast exhibits the best overall performance. The Northeast has a few municipalities with the best practices at a national level, but this macro-region has significant heterogeneity in performance levels. The South has a more homogeneous performance, but the best-performing municipalities in this macro-region are still far from Brazil's best practices.

Keywords: Malmquist index, Water services, Brazilian macro-regions, Composite Indicators, Data Envelopment Analysis

A Non-Convex Global Malmquist index to Compare the Performance of Water Services among Brazilian Macro-Regions

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Introduction

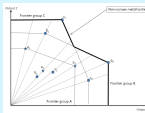
- Studies on the efficiency of water services tend to focus on the overall assessment **without distinguishing regional specificity**.
- The study of the impact of **regional differences** on service performance is particularly relevant in Brazil.
- This paper aims to benchmark the **performance of water supply and sanitation services** among Brazilian macro-regions using an innovative **Global pseudo-Malmquist index**.

Methodology

- The framework's relevance is illustrated using data of the Brazilian water and sanitation regulator, collected at the municipality level for the year 2019.
- The groups compared correspond to **three Brazilian macro-regions**.
- We estimate a **composite indicator**, according to the **Benefit-of-the-Doubt (BoD) framework**.
- A **Global Pseudo-Malmquist index with a Non-Convex meta-frontier** is estimated.

Illustrative example

Group A		Group B		Group C	
DMU's output 1	DMU's output 2	DMU's output 1	DMU's output 2	DMU's output 1	DMU's output 2
x_1	2.1	5.6	x_1	5.5	12.2
x_2	5.2	5.9	x_2	4.4	1.8
x_3	10.8	6.7	x_3	16.5	7.2
			x_4	8.7	14.4
			x_5	7.1	5.7
			x_6	13.1	4.4



θ_j	α_j	β_j	γ_j	δ_j	ϵ_j	ζ_j
A,B	1.10	0.85	1.20	0.98	1.05	1.20
B,C	1.10	1.12	0.98	1.05	1.20	1.05
A,C	1.21	0.95	1.27	0.98	1.05	1.20
C,M	-	-	-	0.93	1.05	1.20
B,M	-	-	-	0.93	1.05	1.20
A,M	-	-	-	0.72	1.05	1.20

DMU	DMU 1	DMU 2	DMU 3	DMU 4	DMU 5	DMU 6	DMU 7	DMU 8	DMU 9	DMU 10
DMU 1	1	0.71	0.86	0.66	0.67	0.65	0.67	0.65	0.67	0.65
DMU 2	0.71	1	0.96	0.66	0.67	0.65	0.67	0.65	0.67	0.65
DMU 3	0.86	0.96	1	1	0.79	1	0.79	1	0.79	1
Geometric average	0.80	0.77	0.86	0.66	0.65	0.67	0.65	0.67	0.65	0.65

Results



- Southeast has the best overall performance.**
- Northeast** has a few municipalities within the best practices at a national level, but it has **significant heterogeneity** in performance levels.
- South** has a **more homogeneous performance**, but the **best-performing municipalities** in this macro-region are still **far from Brazil's best practices**.

Conclusions



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ANALYTICS FOR A BETTER WORLD



Submissão #27

Noise pollution in vehicle routing problem formulations

Cláudia Pereira, António G. Ramos

The current distribution of goods causes serious problems in urban areas due to various external negativities, such as air and noise pollution. Urban goods distribution is of particular importance, as heavy and light goods vehicles still represent the majority of freight vehicles, and generate high noise levels. Exposure to noise levels is a significant problem, as being exposed to higher than recommended noise levels causes adverse effects on the health and well-being of individuals. Noise pollution has not received the same attention in the vehicle route problem literature as other negative externalities such as air pollution. This paper contextualizes noise pollution within the Vehicle Route Problem, bridges the gap with other scientific areas dealing with the impact of noise caused by road transport, and identifies how the minimization of adverse effects caused by noise is modeled in the Vehicle Route Problem.

Keywords: City logistics, Urban freight, Transport sustainability

Noise pollution in vehicle routing problem formulations

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ABSTRACT

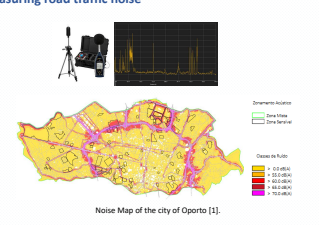
Current distribution of goods causes severe problems in urban areas due to several external negativities, such as air and noise pollution. Urban goods distribution is of particular importance since heavy and light goods vehicles still represent the majority of freight vehicles and generate high levels of noise.

The exposure to noise levels is a significant problem since being exposed to higher than recommended noise levels causes adverse effects on individuals' health and well-being.

Noise pollution has not received the same attention in the Vehicle Route Problem as other negative externalities such as air pollution.

This paper contextualises noise pollution within the Vehicle Route Problem, establishes a bridge with other scientific areas dealing with the noise impact caused by road transport, and identifies how the minimisation of the adverse effects caused by noise on the population exposed to the Vehicle Route Problem is modelled.


1 Measuring road traffic noise



Noise Map of the city of Oporto [1].

2 Noise emission models [2]

- CoRTN model
- SonRoad model
- RLS 90 model
- NIMPA-Routes-2008 model
- Harmonoise model
- Nord 2000 model
- Crossos model
- FHWA model
- ASI RTN-Model



Sound levels by mode of transport [3]

$$L_{road}(f) = a_0(f) + b_0(f) \log\left(\frac{v}{v_{ref}}\right) \quad L_{roll}(f) \text{ - rolling noise}$$

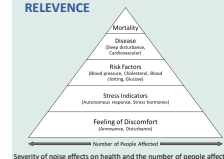
$$L_{pop}(f) = a_1(f) + b_1(f) \left(\frac{v - v_{ref}}{v_{ref}}\right) \quad L_{pop}(f) \text{ - population noise}$$

Harmonoise model [2]

3 Approaches to noise in the context of VRP

- Minimise Costs
 - Cost of noise emissions per ton and distance travelled
 - External costs are allocated to the edges of the network
 - Contingent Valuation Method
 - Noise level criteria
 - Disturbance caused by noise
- Cost of over-threshold of noise emissions

RELEVANCE



Severity of noise effects on health and the number of people affected [4]

References

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[3] IPEA (2004). *O Ruído e a Cidade*. Portuguese Environment Agency.

[4] World Health Organization (2011). Burden of disease from environmental noise. Quantification of healthy life years lost in Europe. World Health Organization. Regional Office for Europe

Acknowledgments

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Submissão #28

Planning visits of home care teams with continuity of care and synchronization - a case study

Ana Raquel de Aguiar, Isabel Gomes, Tânia Ramos

The rising health care expenditure can be decelerated through a proper articulation between the health and social systems. An example is the early discharge of patients no longer requiring specialized medical treatment at hospitals. The care required may be provided by a combination of primary care nurses and social care provided at home. However, social organizations have difficulty in planning these visits due to the problem complexity and the inexistence of decision support systems, generating plans with poor human resource capacity allocation. APOIO is a social organization that provides care to two types of patients: semi-dependent patients, requiring visits of one caregiver, and bedridden patients, requiring two caregivers. Currently, the service is organized in two route types (one for patients requiring one caregiver and another for patients needing two caregivers), planned independently. A MIP model is proposed to support efficient planning, introducing continuity of care and synchronization of single caregiver teams in bedridden visits. Among its planning decisions are the number of teams of each type, the visits sequencing and their starting times, while minimizing total service and travel time. The solutions obtained suggest up to two fewer caregivers when compared to the current planning, enabling waiting list reductions.

Keywords: Home care, Routing and Scheduling, Mathematical Programming



Planning visits of home care teams with continuity of care and synchronization – a case study

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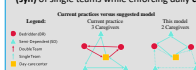
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Context

Sociodemographic trends along with healthcare delivery reforms have been raising the demand for home care services. Organizations providing these services must increase the efficiency of their operational plans, as they already present long waiting lists and must prioritize who to serve. This work aims to develop a MIP model to support the operational planning, so that a better use of caregivers' working time will allow the provision of service to more patients. It advances the literature by considering heterogeneous teams, composed of one or two caregivers. Moreover, when two caregivers are needed to perform one visit, the model may propose the allocation of one double team or the synchronization of two teams of one single caregiver.

Home Care Model Features

Heterogeneous teams, of one or two caregivers, which serve patients requiring one (semi-dependent patients) or two caregivers (for bedridden patients). Efficiency gains in caregiver capacity by allowing **synchronization (syn)** of single teams while enforcing daily **continuity of care** is studied.



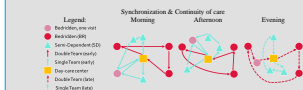
The model designs routes, assigns tasks to teams, decides starting times, the number of teams of each type and when to use synchronization.

Objective function - To minimize working and traveling times. Lunch break time serves as a penalty for the number of caregivers.



The number of teams of each type is bounded by the available caregivers and vehicles. Thus, the proportion of service types may lead to different needs in team schemes (left).

Continuity of care is defined as the preference to allocate the same team through the planning horizon. Since the horizon is longer than a shift, at most two teams can be allocated to a patient.



Daily continuity of care and synchronization are modeled simultaneously, assuring continuity of care by transferring bedridden patients to single teams.

Conclusions

The developed model proposed solutions that increased the organization's capacity to answer home care requests, while complying with all organizational policies. In comparison to the current situation, the proposed model reduced the number of caregivers required by two, which are now free to serve more patients.

Case-Study

The partner, APOIO, provides home care services namely, support on the activities of daily living (medication assistance, home cleaning) and meal delivery.

- **Patient typologies:**
 - Bedridden (visits require 2 caregivers)
 - Semi-dependent (visits require 1 caregiver)
- **Home care:** 40 daily requests
- **Lunch distribution:** 100 meals
- **Homogeneous staff:** 9 caregivers
- **Homogeneous fleet:** 6 cars
- **Working period:** from 8 a.m. to 8 p.m.
- **Shift length:** 8 hours

Manual planning:

- Independent manual plan for each team type
- No synchronization of teams is allowed



Results



- Single teams serve semi-dependent patients and double teams serve bedridden patients exclusively.
- Uses all 9 caregivers.
- Uses all 6 cars (6 routes).
- No synchronization allowed.
- Some waiting/idle times.
- Single teams can synchronize and serve bedridden patients; double teams can serve semi-dependent patients.
- Only 7 caregivers.
- Uses 5 cars.
- Synchronization allowed.
- Less waiting/idle times.

Allowing double teams to serve semi-dependent patients (integrated solve) reduces the number of caregivers in one.

Synchronization is the feature that most increases efficiency, allowing a reduction of two caregivers, but it exposes the routing plan to uncertainty.

When single teams synchronize, they perform sequences of the routes together, suggesting potential operational cost reduction through car sharing.

Submissão #29

Exploring the unit commitment problem to assess the potential of hydroelectric flexible technologies

Flávia Barbosa, Luis Guimarães, Armando Leitão

Hydropower plants have a very long lifetime. To evaluate the total costs and benefits of both the initial installation and the upgrades resulting from new flexible technologies, we developed a unit commitment problem (UCP) focusing on the OPEX costs. The UCP in electrical power production is a mathematical optimization problem where the output of electrical generators is coordinated to achieve some common targets. Our model minimizes simultaneously three components of costs: start-ups and planned and unplanned interventions costs. The unplanned intervention costs are computed considering the risk of a breakdown and restoring an asset to a better condition. Moreover, we evaluate the usage of the hydroelectric technologies proposed in the European project XFLEX HYDRO to provide enhanced flexibility services to the European power system. Each technology comes with distinct possibilities and limits in terms of operating modes, thus introducing different risk profiles in the operation of the units.

Keywords: Hydropower plants, Unit commitment problem, Asset management

XFLEX HYDRO Exploring the unit commitment problem to assess the potential of hydroelectric flexible technologies

Flávia Barbosa | Luís Guimarães | Armando Leitão

Pumped-storage

- Frades 2 (EDP)
- Alqueva (EDP)
- Z'Mutt (ALPIQ)
- Grand-Maison (EDF)<

Technologies

- Variable Speed (FSFC)
- Variable Speed (DFIM)
- Smart Power Plant Supervisor
- Hydraulic short cut

Storage

- Caniçada (EDP)
- Alto Lindoso (EDP)

Technologies

- Variable Speed (FSFC)
- Variable Speed (DFIM)
- Smart Power Plant Supervisor

Run of River

- Vogelrün (EDF)

Technologies

- Variable Speed (FSFC)
- Smart Power Plant Supervisor
- Hydro-battery-hybrid

RQ: How to evaluate the total costs and benefits of both the initial installation and the upgrades resulting from new flexible technologies?

Costs

Basic

Production

- Start-Up (Degradation)

Planned intervention

- Fixed logistics Costs (manpower, technical interventions)

Unplanned intervention

- risk of a breakdown and restoring an asset to a better condition

Supplementary

Water opportunity

- Mandatory sale by law
- Loss through evaporation and soil absorption

Technologies

- The operating conditions affect the useful life of the unit (its wear and tear of the unit)
- related to amount of time each operating mode is used

Unit Commitment Problem

- Each technology comes with distinct possibilities and limits in terms of operating modes, introducing different risk profiles

The UCP in electrical power production is a mathematical optimization problem where the output of electrical generators is coordinated to achieve some common targets, while minimizing simultaneously all components of costs.

Submissão #30

Is makespan a good productivity metric for dynamic scheduling problems?

Gonçalo Figueira

Makespan is the most popular productivity metric used in scheduling problems. By promoting compact schedules, it minimizes setups, idle times and inefficiencies, while balancing machines. However, that might not work so well in many real-world settings, which are dynamic, i.e., where schedules are created/ revised continuously with dispatching rules (pure online approaches), or periodically in the so-called rolling-horizon procedures. In the latter case, the completion time of the last operation (i.e., the makespan) in a given iteration becomes irrelevant in subsequent iterations, as new orders arrive. Motivated by a real-world case study of a flexible job shop setting, we investigate this issue. We propose, analyze and simulate alternative productivity metrics for this and other production settings, including classical and flexible job shops, identical and unrelated machines, and with and without sequence-dependent setup times. We show the relative performance of each metric in a variety of scenarios.

Keywords: Scheduling, Manufacturing, Real-world application

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Is makespan a good productivity metric for dynamic scheduling problems?

Gonçalo Figueira
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2021
MULTITASKING
BETTER WORLD

1 Context

Many real-world scheduling problems are dynamic, and so rescheduling is constantly necessary, as new orders arrive and processing times are updated.

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed
Schedule on Tuesday		█								
Schedule on Wednesday			█							
Schedule on Thursday				█						

Fixed Schedule Detailed Schedule

2 Challenge

Makespan is the most popular productivity metric used in scheduling problems. But in a dynamic setting, the completion time of the last operation in a given iteration becomes irrelevant in subsequent iterations, as new orders arrive.

this will change 420

3 Illustrative Example

1

M1	C	B2		A2
M2	B1	D		A1

2

M1	C	B2	ST	A2
M2	B1	ST	A1	D

t₀ t₁ t₂ t₃

- Consider that at t₂ new orders arrive and the schedule from that point onwards is revised
- In ② the makespan is better, but the schedule is not more compact

4 Alternative Metrics

- Makespan (MS):
 $MS = \max_{i \in Op} (F_i)$
- Remaining Workload (RW):
 $RW(t) = \sum_{i \in Op} \max(0, F_i - \max(S_i, t))$
- Integrated Remaining Workload (IRW):
 $IRW = \int_0^{MS} \sum_{i \in Op} \max(0, F_i - \max(S_i, t)) dt$
- Weighted Operation Completion Times (WOCT):
 $WOCT = \sum_{i \in Op} F_i \cdot p_i$

Analytical Result: minimizing IRW \Leftrightarrow minimizing WOCT

5 Simulation Experiments

We have simulated:

- 3 metrics (MS, RW and WOCT)
- 192 scenarios (different combinations of machines, jobs and loads)
- 5 replications
- Each with a rolling-horizon of 5 iterations

At the end of the rolling-horizon we measure 3 indicators: Makespan, Tardiness and Flow Time

Makespan

-0.35% -0.81%

Tardiness

-1.65% -1.84%

Flow Time

-2.75% -2.71%

Percentual improvement of RW and WOCT, compared to MS

Main takeaways:

- Both RW and WOCT improve not only productivity (Makespan), but also service level (Tardiness) and work in process (Flow Time)
- Improvements are very consistent in the different scenarios tested
- 0.81% in Makespan might seem small, but this indicator is very sensitive, so it is actually quite significant

Submissão #31

A Sensor Placement Problem in Waste Management based on a Clustered Vehicle Routing Problem with Profits and Detours

Carolina Soares de Moraes, Daniele Vigo, Tânia Ramos, Ana Barbosa-Póvoa

Waste management systems face inefficient collection and transportation of solid waste as a high uncertainty is associated with waste accumulation. If sensor information on the amount of waste inside bins is used to feed dynamic optimization approaches, more efficient collection routes can be designed. As the investment cost of sensors is still very high, we investigate how to select a reduced sample of bins to monitor, considering the value of information provided by sensors. To solve a sensor placement problem in waste management, we propose a two-phase methodology: in the first phase, the tactical problem of selecting a sample of bins to monitor is addressed; then, in the second phase, and depending on information transmitted by the installed sensors, a CluVRPP with Detours is operationally solved to decide the detours to take from a skeleton of routes that are regularly performed to visit unmonitored bins. A real-world problem is solved using our methodology, and three scenarios are assessed by a cost-benefit analysis: 1) no sensors - all bins are regularly visited; 2) sensors in all bins - bins are visited only when needed; 3) a set of bins is monitored - a regular route is performed and, when needed, a detour is taken.

Keywords: Logistics, Sensors, Mixed-Integer Linear Programming, Vehicle Routing Problems, Detours



A Sensor Placement Problem in Waste Management based on a Clustered Vehicle Routing Problem with Profits and Detours

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Introduction

Waste management systems face inefficient collection of solid waste as a high uncertainty is associated with waste accumulation. If sensor information on the amount of waste inside bins is used to feed dynamic optimization approaches, more efficient collection routes can be designed. As the investment cost of sensors is still very high, we propose a strategy to reduce the impact of investment costs to implement smart collection systems in solid waste.

A Tactical/Operational Sensor Placement Problem

To select a sample of strategic bins to monitor so that optimized routes can be designed using real-time information

Tactical decision:
Which bins should have a sensor?

Operational decision:
How to design the optimized collection routes to perform?

Two-Phase Methodology

Some bins require a more regular collection frequency and can be visited every N days. Others have a more unpredictable behavior and must be monitored: similar non-regular bins located nearby are grouped and only one sensor is installed in each non-regular cluster.

PHASE 1 - TACTICAL DECISION: Which bins should be equipped with sensors?

Step 1: Clustering Algorithm (Homogeneous clusters)

Step 2: Classification (Regular bins and non-regular clusters)

Step 3: Sensing (Real-time information on non-regular clusters fill needs (how sensor per cluster))

PHASE 2 - OPERATIONAL DECISION: Which detours to perform? How many routes to operate? Optimal visiting sequence for each route?

Step 4: Solve (Non-regular clusters (detour path) (DHP between entry exit points))

Step 5: CluVRPP with Detours

OUTPUTS: Dynamic routes that regularly visit all regular bins and perform some detours (plans) to visit non-regular clusters, based on real-time information

Every N days, when designing the regular routes, plan which non-regular clusters to visit, based on real-time information provided by sensors. When necessary, non-regular clusters are visited through detours made from the regular routes.

Case Study

The methodology was tested using a real-case (98 bins). Different scenarios were considered and different configuration possibilities for the 1st phase of the methodology were studied.

Scenario	Number of Sensors	Number of Routes
Scenario 1	0	1
Scenario 2	98	1
Scenario 3	12	1

Cost-benefit analysis

Additional scenarios: no sensors (all bins are visited on a regular basis), sensors in all bins (bins are visited when it is required).

Value of perfect info = (1 587,9 € - 409,1 €) / 98 sensors = 12 €/sensor

Conclusions

- A more profitable collection operation depends not only on how many sensors are installed, but also on where sensors are located (in which bins);
- When clustering bins, it results more profitable to consider a neutral scenario where coordinates and filling rates have same importance since in this case more homogeneous non-regular clusters are defined;
- Around 25-30% of the bins should receive a sensor so that a higher estimated value of perfect information is achieved;
- A risk seeking approach results in a more profitable collection operation than a risk averse approach, but overflows may occur (lower service level).

Acknowledgments

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Submissão #32

Vehicle Routing Problem to on-time transportation of biological products on healthcare centres

Maria Teresa Pereira, Marisa Oliveira, Fernanda Amélia Ferreira, Alcinda Barreiras

This paper presents a Vehicle Routing Problem (VRP) applied in the field of health care to determine a set of vehicle routes to perform on-time transportation of biological products from the health centres where they are collected from the patients to the hospital laboratory for further processing and analysis, taking into consideration the technical issues related with this problematic. The project work is intended to deploy an existing solution in CPLEX software and to develop Vehicle Routing Problem with Pick-Ups and Deliveries (VRPPD) in a way it is possible to perform effectively collections of biological products and at the same time deliver medical supplies such as gloves, masks, sanitation accessories and disposable tools to the health units. In addition, it is aimed to implement the solution for the network with the increased number of units to be served. The construction of the mathematical model allowed to build the route efficiently, taking into account the distances covered, service times, travel times, total time of the route and allowed the vehicle to be free to perform other tasks. Acknowledgments: This work is funded by the European Regional Development Fund through the Regional Operational Program North 2020, within the scope of Project GreenHealth-Digital strategies in biological assets to improve well-being and promote green health, Norte-01-0145-FEDER-000042.

Keywords: VRP, Transportation, biological products, Healthcare

Vehicle Routing Problem to on-time transportation of biological products on healthcare centres

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Introduction

A Vehicle Routing Problem (VRP) is applied:

- In the field of health care for biological samples collection
- To determine a set of vehicle routes
- Taking into consideration the technical issues related with this problematic

Determine a set of vehicle routes for biological samples collection

Health centres → Hospital laboratory

Methodology

- Hospital logistics analysis
- Study the legislation on the transport of biological products
- Studies and research on VRP namely their variants and applications
- Literature review of VRP models in the context of health care
- Analysis and characterization of the transport process of biological products currently practiced by USLM
- Mathematical formulation for solving the routing problem with time windows
- Model implementation and solution using IBM CPLEX software

Problem Definition

- The Local Health Unit of Matosinhos (USLM) applies a certain way to conduct clinical analyses
- The collection of samples is carried out in health centers
- Biological products are sent to Hospital Pedro Hispano - central laboratory for their examination
- Instead of concentrating patients for clinical analysis at a single point, to distribute them by geographic area local residents can currently do their clinical analysis at the health centers
- 70% of collected samples correspond to blood which requires special attention in the development of this work
- After collecting blood and before transporting to the laboratory, it is necessary to separate the sample elements (red blood cells, plasma) - centrifugation process
- Not all the health centers are equipped with the centrifugation machine
- There are two types of blood
 - centrifugated
 - non-centrifugated
- That determines different requirements for their transportation
- The blood collected in the service points that do not have centrifuges should be processed within two hours after collection with a 30-minute tolerance
- The use of centrifuges allows the samples to remain in sufficient quality to perform exams up to 4 hours after undergoing the centrifugation process
- The problem is that initially established route for transporting non-centrifugated samples (from CS Matosinhos, USF Porta do Sol, CS S5o Mamede de Infesta, CS Senhora da Hora) do not satisfy the requirement corresponding delivery time limit of 2 hours (tolerance of 30 mins)

Model

Parameters:

- $NHCU$ Health Units $\{1, 2, \dots, n\}$
- a_i Lower limit of time window of i (\bullet $NHCU$)
- b_i Upper limit of time window of i (\bullet $NHCU$)
- t_{ij} Travel time from i to j (\bullet $NHCU \cup \{0\}$) $\forall NHCU \cup \{0\}$
- E_j Service time, corresponds to the time the driver spends collecting samples from each i (\bullet $NHCU$)

Decision variables:

- x_{ij} Binary variable, $x_{ij} = 1$ if the vehicle travels from i to j ; otherwise $x_{ij} = 0$
- s_i Instant when the vehicle starts service at i (\bullet $NHCU \cup \{0\}$)

Objective function:

Min $\sum_{i \in NHCU} s_i$ (1)

Constraints:

- $s_i + t_{ij} - s_j \geq 0$ $\forall i, j \in NHCU$ (2)
- $s_i \geq a_i$ $\forall i \in NHCU$ (3)
- $s_i + E_j - s_j + (b_j - a_i + t_{ij}) \cdot x_{ij} \leq b_j - a_i$ $\forall i, j \in NHCU, j \neq i$ (4)
- $\sum_{j \in NHCU} x_{ij} = 1$ $\forall i \in NHCU$ (5)
- $\sum_{i \in NHCU} x_{ij} = 1$ $\forall j \in NHCU$ (6)
- $s_i \leq b_i$ $\forall i \in NHCU$ (7)
- $a_i + t_{ij} \leq s_{i+1}$ $\forall i, j \in NHCU$ (8)

Main Results

Health Unit	Time Window (min)	Service Time (min)	Travel Time (min)	Route
CS Matosinhos	0:00	10:00	0:00	0:00
USF Porta do Sol	0:15	0:10	0:10	0:15
CS S5o Mamede de Infesta	0:30	0:20	0:20	0:30
CS Senhora da Hora	0:45	0:30	0:30	0:45
CS Matosinhos	1:00	1:00	1:00	1:00

Table 2. Non-waiting period in Health Units w/o centrifuges

- Waiting time occurs at CS Porta do Sol
 - once the truck arrives at the point 6 mins before the harvest period is over which adds extra time to the total duration of the trip even though arrival at PHU satisfies the defined timeframes
 - it is possible to avoid it by increasing the lower limit of time window for CS S5o Mamede de Infesta to 32:45

Conclusions

- The construction of the mathematical model allowed:
- Build the route efficiently
- Taking into account
 - the distances covered
 - service times
 - travel times
 - total time of the route
- Allowed the vehicle to be free to perform other tasks
- Implement the solution for the network with the increased number of units to be served


Submissão #33

Optimisation of Asset Management Investments using the Infrastructure Value Index


Hermilio C. Vilarinho Fernandes, Flávia Barbosa, Henriqueta Nóvoa, Ana Camanho

Proper management of water infrastructures is crucial to enhance the three sustainability dimensions of urban settings: better water services for the People, respect for limited water resources in the Planet, and Prosperity. This work proposes a novel approach to select infrastructure investment projects in water supply facilities under the framework of asset management. The proposed optimisation model chooses the portfolio of projects that maximise the Infrastructure Value Index (IVI). The IVI has been discussed as a tool to characterise water service infrastructure and address investment planning to overcome risks. It was initially designed as the ratio between an asset's current value and its replacement cost and is currently applied for asset management by Portuguese water companies. The use of the model is demonstrated with data provided by a real-world case study. The results obtained were discussed and validated with company managers. This research shows that the IVI is a valuable tool to prioritise capital investment initiatives in water systems, and its use can be extended to infrastructures in other sectors.

Keywords: Asset management, Capital investment planning, Infrastructure value index, Performance indicator, Optimisation



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OPTIMISATION OF ASSET MANAGEMENT INVESTMENTS USING THE INFRASTRUCTURE VALUE INDEX.

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Research Question: how to prioritise capital investments in water systems?

- Select infrastructure investment projects in water supply facilities.
- Optimisation model - maximise the average Infrastructure Value Index (IVI).
- IVI - ratio between an asset's current value and its replacement cost.

Workflow

List of Project Candidates

→

Estimation of Parameters:
How much a project...
...extends asset's life (Δ)
...transforms an asset (β)
...will cost ($CapEx$)

→

Optimisation Model

→

Selected Projects

The IVI

IVI Range

0% | 40% | 60% | 100%

Recommendation Range

IVI Formulation

For N-Assets:
$$IVI_{T_n} = \frac{\sum_{i=1}^N \frac{RV_i^{(n)} - RC_i}{UV_i^{(n)}}}{\sum_{i=1}^N RC_i}$$

For One Asset:
$$IVI_{T_n} = \frac{RV_n^{(n)} - RC_n}{UV_n^{(n)}}$$

Average IVI - N assets and (T) years

$$IVI_{T_n} = \frac{\sum_{i=1}^N \sum_{t=1}^T IVI_{i,t}}{N \times (T-1)}$$

$RV_n^{(n)}$ = residual life
 $UV_n^{(n)}$ = useful life
 RC_n = replacement cost

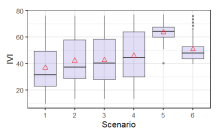
Case Study

- Data provided by *Agua do Douro e Pavia (ADDP)* for the infrastructure *Arnim Pumping Station*.
- Six scenarios considered for analysis.

Scenario	Description	Budget
1	No investment in 3 years	
2	ADDP's original planning	0.4753€ (0.0000€)
3	Maximise IVI - ADPP's capital schedule	0.4753€ (0.0000€)
4	Maximise IVI - No restrictions to annual capital	0.4753€ (0.0000€)
5	Minimise capital - Minimum IVI - 40% Total renewal project.	0.4753€ (0.0000€)
6	Minimise capital - Minimum IVI - 40% Partial rehabilitation projects.	0.4753€ (0.0000€)

Results

- Project portfolios determined for all scenarios.
- Higher Avg IVI in scenarios 3 and 4 compared to 2.
- Considering potential projects for all low-IVI assets results in lower variation in scenarios 5 and 6.



Conclusions

- The IVI is a valuable tool to prioritise capital investment initiatives in water systems' asset management.
- The methodology can be employed in different businesses.

Future Work

- Address all the possible investment initiatives for the existing assets, allowing a broader set of project options to be considered.
- More accurate estimates of the needed parameters: Δ , β and $CapEx$ should be explored aiming to generate more precise outcomes.

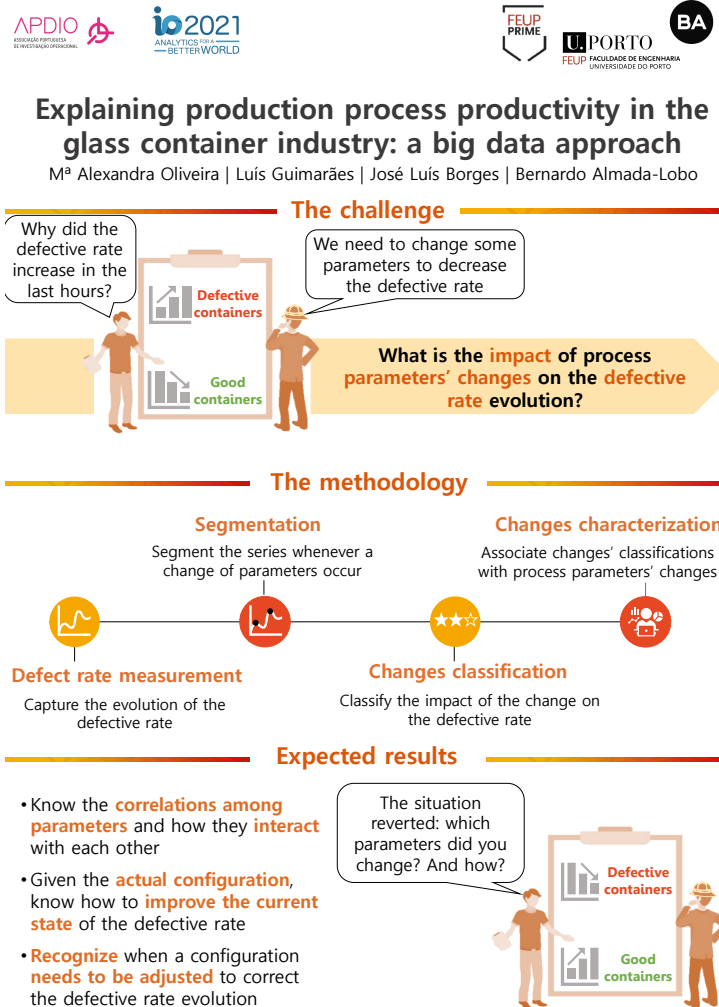
Submissão #34

Explaining production process productivity in the glass container industry: a big data approach

Maria Alexandra Ramalho de Oliveira, Luis Guimarães, José Borges, Bernardo Almada-Lobo

The current global market is defined by high competitiveness, caused mainly by increased supply and customer expectations. Faced with this scenario, companies must strive to be more efficient and effective, so quality and productivity play a significant role. The capability to improve both the quality and productivity of the delivered service will dictate the company's position in the market. With the rise of Industry 4.0, it became clear for organizations the importance of analyzing the vast amounts of data generated over the years by their core processes. This work is motivated by a collaboration with the largest Portuguese glass container manufacturer. The goal is to minimize production losses by leveraging data-driven models to support and optimize decision-making. However, the dispersion of data increases the difficulty of replicating the best historical production cycles and creates challenges in understanding the quality defects causes. Therefore, it is crucial to understand the process in the first stage by diagnosing the production losses behavior. We present an approach to identify patterns in the containers' defective rates and explain them by estimating the impact of controllable and uncontrollable production process variables. Resulting from the application of the proposed work, we expect to decrease production losses, reduce the dependency on worker's experience, and understand the causes of the identified patterns.

Keywords: Glass container production, Process improvement, Machine learning



Submissão #35

Outsourcing Optimization in Footwear Industry: The Case of a Portuguese Company

Raquel Francisco, Eliana Costa E Silva, Sandra P. Sousa, Vítor Braga

In the footwear industry, when market's demand exceeds the company's manufacturing capacity, subcontracting is generally considered. The downward trend in the number of pairs per order was accentuated with the COVID-19 pandemic. In order to give a quick and efficient response to customers', several companies consider that each order can, in principle, be assigned for internal or external production. The present work presents an empirical study with real data from a company in the footwear sector located at the Tâmega e Sousa Region. The aim is to propose a model for assisting in the production planning decision-making process, for the two main phases in the manufacturing process. With the aim of minimizing the overall cost, each order must be assigned for one of the available subcontractors or for internal production, while taking into account the conditions that most influence the processes. One year data, provided by the company, is used to test the model, considering biweekly and monthly planning. Furthermore, taking the company's current process, grouping the orders of the same article, is also considered in the tests. The results show the economic advantage in using mathematical modeling. In fact, for the tested instances cost reductions were found in both phases of the manufactured process. This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia through project UIDB/04728/2020

Keywords: Outsourcing, Footwear Industry, Binary Linear Programming, Assignment Problem

Outsourcing Optimization in Footwear Industry: The Case of a Portuguese Company

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The market is changing, and the downward trend in the number of pairs per order was accentuated with the COVID-19 pandemic. Customers do not want to risk accumulating stocks in their warehouses. As so they expect the supplier to have a quick and efficient response capacity for replacement of article with high demand. Production planning of footwear companies often depends on outsourcing services. The company must select from a set of service providers with the objective of maximizing production and minimizing costs. To contribute to this, the objective of the present work was to develop a tool to assist the production planning. It is expected that it will contribute to improve the decision of resorting to outsourcing.

THE COMPANY

- Exports 100% of its production
- 500 000 pairs per year
- Production peaks
- 2 collections:
 - Spring-Summer and Autumn-Winter
- Lack of qualified labor
- It uses outsourcing

DATABASE

Year: 2020
orders: 5250 encomendas
pairs: 470 641
clients: 97

Number of pairs, per country: 33 countries

Decision Variables

$$x_{ij} = \begin{cases} 1 & \text{if order } j \text{ is produced at factory } i \\ 0 & \text{otherwise} \end{cases}$$

Parameters

- $i \in \{1, \dots, m\}$ designates the m available factories;
- $j \in \{1, \dots, n\}$ designates the n orders;
- c_j is the base cost of producing each pair on order j ;
- a_{ij} is the number of pairs in order j ;
- w_i is the percentage factor cost of factory i ;
- p_i is the production capacity of factory i .

Binary programming model

$$\min \sum_{j=1}^n \sum_{i=1}^m a_{ij} c_j (1 + w_i) x_{ij}$$

s.t.

$$\sum_{i=1}^m x_{ij} = 1, \quad \forall j \in \{1, \dots, n\}$$

$$\sum_{j=1}^n a_{ij} x_{ij} \leq p_i, \quad \forall i \in \{1, \dots, m\}$$

$$x_{ij} \in \{0, 1\}, i = 1, \dots, j = 1, \dots, m$$

Results for Cutting - Sewing (C-S)

	March-April	May	June	July	August	September
Using the developed approach	20,790	58,536	48,341	76,982	16,355	36,497
Number of pairs	13,001	37,186	30,491	48,284	10,051	22,847
Outsourcing, in pairs	420	21	619	1,738	925	943
Unused capacity	11	30.5	9.5	31	9	15.6
Number of days needed to produce	87,604.60	286,725.10	223,741.68	371,579.71	74,521.40	180,030.85
Production cost	87,604.60	286,725.10	223,741.68	371,579.71	74,521.40	180,030.85
Outsourcing cost	37,195	36,475	36,905	37,285	38,205	37,895
Quantity of orders to produce	189	647	532	853	205	494
% Internal	62.81%	63.53%	63.07%	62.72%	61.48%	62.00%
% Outsourcing	37.19%	36.47%	36.90%	37.28%	38.52%	37.89%

Results for Assembly - Finishing (A-F)

	March-April	May	June	July	August	September
Using the developed approach	30,700	58,536	48,341	76,982	16,355	36,497
Number of pairs	9,701	25,036	20,319	32,986	6,657	15,508
Outsourcing, in pairs	308	89	659	18	120	251
Unused capacity	12	33.5	28	28	9.5	21
Number of days needed to produce	6,358.58	182,772.29	152,450.01	243,318.69	51,474.83	114,706.00
Production cost	24,517.25	73,503.99	61,053.21	99,611.43	20,690.33	46,398.15
Outsourcing cost	136	147	52	853	305	494
Quantity of orders to produce	37,975	87,275	87,915	97,195	58,075	87,575
% Internal	42.00%	42.77%	42.00%	42.80%	41.90%	42.47%
% Outsourcing	57.99%	57.22%	57.99%	57.19%	58.07%	57.52%

Results for Cutting - Sewing (C-S)

Results for Assembly - Finishing (A-F)

Results for Cutting - Sewing (C-S)

Results for Assembly - Finishing (A-F)

The results obtained show that there is an economic advantage in using mathematical modeling for planning the production of orders. In fact, for the instances tested, the company would reduce the 3.37% of outsourcing in C-S and 7.30% in A-F when compared to its current procedure.

This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia through project UIDB/04728/2020

Submissão #36

Um modelo de decisão bi-objetivo para otimização de portefólios de projetos em serviços administrativos

Jorge Noro, Luis Dias

Este trabalho apresenta um modelo bi-objetivo de otimização para a gestão de portefólios de projetos, centrado no compromisso dos agentes. O modelo maximiza os ganhos (económicos) do portefólio enquanto assegura o compromisso da equipa com a organização. O desenvolvimento de competências dos agentes também é considerado, de modo a melhorar o desempenho da equipa ao longo do tempo. A formulação permite selecionar quais os projetos a serem implementados e por quem. A afetação dos projetos considera a carga de trabalho de cada agente, as suas competências e a forma como essa alocação de novos projetos afeta os seus compromissos com o serviço, através das dimensões de Absorção, Dedicção e Vigor da escala de UWES (escala de compromisso com o serviço de Utrecht), na sua forma reduzida. São apresentados resultados experimentais, num cenário baseado na experiência de serviços administrativos de suporte a projetos de investigação e inovação.


Keywords: Gestão de portefólios de projetos, Compromisso dos agentes com o serviço, Otimização multi-objetivo

UM MODELO DE DECISÃO BI-OBJETIVO PARA OTIMIZAÇÃO DE PORTEFÓLIOS DE PROJETOS EM SERVIÇOS ADMINISTRATIVOS

Como escolher e alocar novos projetos sem perder a equipa?

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RESUMO


Este modelo de decisão bi-objetivo permite selecionar os projetos a executar, otimizando a sua alocação ao portefólio da equipa, tendo em conta:

- o valor de cada projeto para a organização
- o desenvolvimento dos skills da equipa pela experiência

A afetação de portefólios de projetos a equipas dentro das organizações pode contribuir tanto a um aumento do compromisso dos agentes como ao seu desgaste físico ou emocional, logo, do seu compromisso com a organização.

PDA - STAFFING

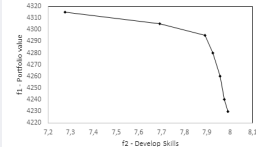
De acordo com a Escala de Utrecht para o Work Engagement, as dimensões do Vigor, Absorção e Dedicção assumem um papel determinante no compromisso dos agentes com a organização.



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RESULTADOS

O modelo permite encontrar os pontos da frente de Pareto



CONCLUSÕES

O modelo possibilita a análise de objetivos conflitantes através de soluções Pareto-ótimas, permitindo aos decisores a seleção do compromisso que preferiam. O compromisso dos agentes resulta da afetação de projetos, que condiciona o desempenho da equipa e organização. O modelo permite atuar sobre o trade-off dado pela necessidade de afetar novos projetos e manter a equipa coesa.

Values for work engagement, before and after allocation, for agent's workload.

Staff member	Final score _{ij}	Score of engagement dimensions, Utrecht Work Engagement Scale, UWES									Maximum Disengagement	
		WES _{ij} = f(VI, AB, DE)										
S _i	P _j	VI _{ij}	AB _{ij}	DE _{ij}	VI _{ij}	AB _{ij}	DE _{ij}	VI	AB	DE		
S ₁	4	0.50	0.22	0.50	0.40	0.20	0.49	-10%	-2%	-	0.6	
S ₂	10	0.39	0.67	0.72	0.08	0.41	0.70	-31%	-26%	-1%	0.6	
S ₃	5	0.83	0.22	0.39	0.58	0.19	0.39	-25%	-9%	-1%	0.6	
S ₄	4	0.83	0.83	1.00	0.87	0.77	1.00	-16%	-7%	-1%	0.2	
S ₅	2	0.67	0.89	0.83	0.87	0.89	0.83	-	-	-	0.2	
Team		64%	57%	69%	48%	49%	68%	-16%	-8%	-1%		
	ΔWES _{ij}	63%									55%	


Starting Skills considering training and experience profiles

C _{ij} ^e ∈ [0, 1]	Profile	BCT		PE		IT	
		Have	Not Have	Have	Not have	Have	Not have
0.00 - 0.24	Basic		X		X		X
0.25 - 0.49	Intermediate low	X			X		X
0.50 - 0.74	Intermediate High	X		X			X
0.75 - 1.00	Advanced			X		X	

Legend: BCT - Basic Curricular Training, courses and other suitable training; PE - Professional Experience, and accumulated service time in related functions; IT - Internal Tutoring, assignment on-the-job training

Values for entry and final skills and for agent's workload.

Staff member	Total Projects	Entry Skills, ∇ Proj	Opps Develop Skills		End Skills, ∇ Proj
			Ongoing, C _{ij}	New Proj, C _{ij}	
S ₁	4	0.40	0.48	+0.40	0.88
S ₂	10	0.90	0.60	+0.33	0.92
S ₃	5	0.50	0.10	+0.50	0.60
S ₄	4	0.40	0.42	+0.30	0.82
S ₅	2	0.25	0.80	=0.00	0.80



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Submissão #37

Dynamic Sectorization - Conceptualization and Application

Filipe S. de Sousa, Elif Goksu Ozturk, Maria Margarida Lima, Ana Catarina Nunes, Cristina Lopes, Cristina Teles, Ana Maria Rodrigues, José Soeiro Ferreira

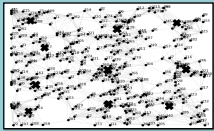
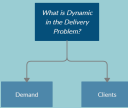
Sectorization is the division of a large area, territory or network into smaller parts considering one or more objectives, intending to optimize or simplify a problem. Dynamic sectorization deals with situations where it is convenient to discretize the time horizon in a certain number of periods. Certainly, the decisions will not be isolated, but they will consider the past and the forthcoming periods. The application areas are diverse and increasing due to the uncertain times in which we live. For example, solving this problem can be useful for delivery companies where the demand is always changing. We propose a conceptualization of dynamic sectorization and apply it to a problem under research related to distribution with variable demand. Furthermore, the solution to that problem is obtained using a Decision Support System developed by the authors. This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-031671.

Keywords: Sectorization, Dynamic Sectorization, Decision Support System

io2021 **Dynamic Sectorization – Conceptualization and Application**


Filipe Sousa¹, Elif Goksu Ozturk^{2,3}, Maria Margarida Lima⁴, Ana Catarina Nunes^{1,4}, Cristina Lopes⁵, Cristina Teles⁴, Ana Maria Rodrigues^{2,4} and José Soeiro Ferreira^{2,5}

¹ISCTE - Instituto Universitário de Lisboa, ²INESCTEC - Technology and Science, ³FEUP - Faculty of Economics, University of Porto, ⁴CEOS-PP, ISCAP, Politécnico do Porto, ⁵FEUP, Faculty of Engineering, University of Porto, ⁶CMAF-GO, Faculdade de Ciências da Universidade de Lisboa

Sectorization	Dynamic Sectorization - Conceptualization
<p>Sectorization is the division of a large area, territory or network into smaller parts considering one or more objectives, intending to optimize or simplify a problem.</p> 	<ul style="list-style-type: none"> Dynamic sectorization deals with situations in which it is relevant to discretize the time horizon in a certain number of periods ($T = 1, 2, \dots, K$). Each period, a new sectorization is performed Decisions will not be isolated but will consider the past and the future periods. 

Delivery Problem

- N facilities with a limited capacity will serve their customers during the next days.
- The location of the customers is known and it does not change over time
- The demand changes over time
- Use of statistical models



OBJECTIVE Design compact, contiguous and balanced sectors for each day, maintaining the sectors similar.

350 CLIENTS
10 FACILITIES
3 DAYS

The problem was solved by the decision support system developed by the authors. It uses multi-criteria optimization algorithms like NSGA-II.

Decision Support System configuration

- In how many periods is the time horizon divided?
3
- Which distribution best represents the behavior of the demand?
 Normal Distribution
 Uniform Distribution
- How much is the percentage of change in demand during the time horizon?
8

Sectorization at $T = 1$
Sectorization at $T = 2$
Sectorization at $T = 3$

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Instituto Universitário de Lisboa

CMR2020 **2020** **FCT** This work is financed by the ERDF - European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-031671.

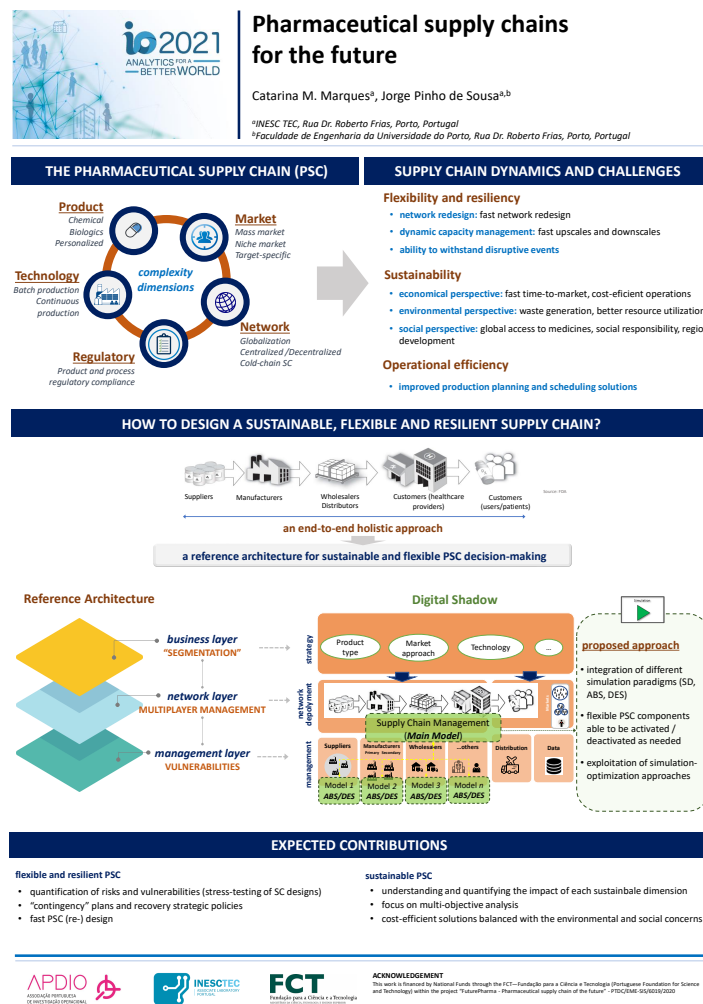
Submissão #38

Pharmaceutical supply chains for the future

Catarina Marques, Jorge Pinho de Sousa

As never before, the COVID-19 pandemic has shown the extraordinary importance of the pharmaceutical industry and its supply chains. In fact, not only pre-existent supply chain weaknesses are being exposed and aggravated, but also technological breakthroughs and operational innovations have been boosted by the urgent need for a fast and direct response to the pandemic. Even if these recent operational initiatives seem to defy some of the current management paradigms, one needs to understand how they will endure in the future. This is particularly relevant to guarantee these general approaches will ensure an uninterrupted and efficient worldwide supply of innovative medicines. In this context, this work aims to present a comprehensive overview of the industry most prominent challenges, as well as to understand the pharmaceutical supply chain network dynamics and idiosyncrasies, in order to develop a reference architecture for supporting high-level decision-making. The main purpose of such architecture is to fast-track vulnerabilities along the distribution chain, and to anticipate the resulting risks propagation across the network in several uncertainty scenarios. This assessment is expected to provide insights to build both proactive operations strategies and reactive plans, fostering enhanced supply chain resiliency and flexibility.

Keywords: Pharmaceutical supply chain, Resiliency, Flexibility, Simulation-optimization, Uncertainty



Submissão #39

Using Reinforcement Learning to select Dispatching Rules for the Flexible Job Shop Scheduling

Nuno Marques, Gonçalo Figueira, Luis Guimarães

With the rise of Industry 4.0, organizations must keep up with the technological evolution and fierce competition. Under this paradigm shift, operations management problems in general, and production scheduling in particular, present new challenges, such as real-time decision making. Therefore, reactive methods such as Dispatching Rules (DRs) are reemerging as a popular choice in dynamic scheduling due to their interpretability, simplicity and overall satisfactory performance in uncertain environments. Over the years, researchers have combined simpler rules to form more performant ones, the so-called Composite Dispatching Rules (CDRs). These studies resort either to extensive domain knowledge to manually compose them, or to methods that automatically generate CDRs, such as, Random Forests or Genetic Programming. Even though CDRs present good performance, the literature is unanimous to state that there is not one rule that works well across diverse Scheduling conditions, that is, light to heavy utilisation and tight to loose due dates. Therefore, this work aims at investigating the suitability of using a Reinforcement Learning (RL) agent. RL's main advantage is its adaptability, as RL agents continuously learn by collecting new observations from the environment. However, key issues, such as the reward function and computational effort, might compromise its performance.

Keywords: Production Scheduling, Reinforcement Learning, Flexible Job Shop, Industry 4.0

Using Reinforcement Learning to Select Dispatching Rules for the Dynamic Flexible Job Shop Scheduling

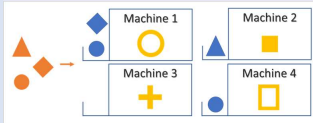
Nuno Marques, Gonçalo Figueira, Luis Guimarães
INESC TEC, Faculty of Engineering, University of Porto

MOTIVATION

- Manufacturing settings are increasingly dynamic and flexible.
- The Dynamic Flexible Job Shop Scheduling Problem (DFJSSP)** is one of the most relevant problems in this context.
- Two main research communities:
 - Operations Research – derives **Dispatching Rules (intuitive, but lack performance)**
 - Machine Learning – using **Reinforcement Learning** to dynamically select Dispatching Rules (**promising, but still quite unexplored**)
- Hypothesis under study: a **Reinforcement Learning (RL) agent that can choose a DR according to the job shop conditions is an effective solution to the DFJSS problem.**

THE DYNAMIC FLEXIBLE JOB SHOP SCHEDULING PROBLEM


- Jobs arrive **stochastically** at the shop
- Operations can be processed by **more than one machine**



- When a machine is idle: select an operation according to DR (**allocation + sequencing**)

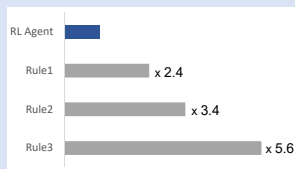
REINFORCEMENT LEARNING CONFIGURATION

Type of RL	Q-Learning , as it allows to use a discrete action set and relies on fewer parameters than Deep Q-Learning
Action set	6 different DRs that can be found in Luo (2020); these were properly modified according to the simulation specificities
Reward	Positive (value: 1) if a decrease in actual tardiness is observed, -1 if otherwise; estimated tardiness and machine utilisation are used when ties occur
State set	7 different states from Luo (2020) regarding utilization, operations and jobs completion rate and tardiness metrics; the domain of the states is [0,1] for generalizability



Sutton, R. Bach, F. and Barto, A., 2018. Reinforcement Learning. 2nd ed. Massachusetts: MIT Press USA, p. 48.

RESULTS AND DISCUSSION



- Performance was measured on a test set composed by 100 replications;
- The RL agent **outperformed** the rules that compose the action set;
- Which is aligned with the initial hypothesis that using different rules for particular job shop conditions would result in **lower tardiness figures**.

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Submissão #40

Genetic Programming: a new way to rethink online fulfillment optimization?

Sérgio Castro, Gonçalo Figueira, Bernardo Almada-Lobo

Online retail represents around 18% of global retail sales. As its growth shows no sign of slowing down, practitioners still face many unresolved challenges. Last mile delivery costs in online retail are often higher than in traditional retail due to the need to ship items from a fulfillment center to a customer address, which results in a challenging dynamic optimization problem. We have investigated an approach based on genetic programming for the online order fulfillment problem. The main advantage over mathematical programming approximations, which dominate the literature, is the easiness in inspecting, reproducing and implementing decision rules. These are critical features for adoption by practitioners. Decision rules were trained and tested on a set of instances that approximate real-world settings. Results show: (1) an improvement of 2,4% over the myopic policy, capturing around 16% of the improvement gap between the myopic policy and a perfect hindsight solution; (2) an improvement of the performance of the generated decision rules with a higher crossover probability and a lower limit on the maximum tree depth; and (3) the most relevant terminals are those related to the problem's costs function, namely the distance to the order location, and the ability to fulfill multi-item orders.

Keywords: Online Fulfillment, Dynamic Optimization, Genetic Programming, Machine Learning


TRUSTAI


Genetic Programming

A new way to rethink online fulfillment optimization?

Sérgio Castro, Gonçalo Figueira, Bernardo Almada-Lobo
INESC-TEC & FEUP

The Setting

Last mile operations, often the most cost-intensive part of e-tailers supply chains (e.g. **Amazon, Alibaba, Farfetch**), require a careful optimization. An important issue is **sequentially deciding from where to ship orders**, as they arrive, given a complex network of supply nodes.

The Challenge

Example - Two warehouses (WH1 and WH2), two SKUs (1 and 2) stored:

WH1

1

1

1

WH2

1

2

2

Order #1: 1 From which warehouse do we ship the ordered product?

Fulfillment cost from WH1 is 10€, while from WH2 is 8€, since WH2 is closer to the delivery point (DP). Thus, we chose WH2. Next order:

Order #2: 1 + 2 Our only option is to split the order between WH1 and WH2, resulting in a fulfillment cost of 18€ for order #2, and a total fulfillment cost of **26€**.

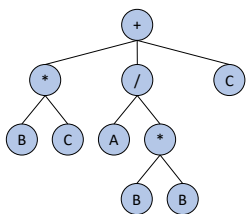
Had we chosen to fulfill order #1 from WH1 for 10€, we could have fulfilled order #2 entirely from WH2, at a cost of 12€, resulting in a total fulfillment cost of **22€**.

This example illustrates that the crux to solving the problem is capturing the **trade-off** between the **immediate myopic costs** and the **future value of the inventory state**.

The Solution & Results

We propose solving the problem using **Genetic Programming**, simulating **decision rules** and using an **evolutionary process to guide the optimization**.

Decision rule (DR) example:

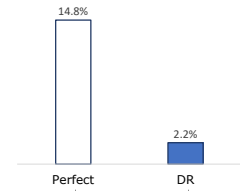


A: Distance from WH to DP (normalized 0-1, 1 -> distance from the DP to the furthest WH);
B: % of items in the order the WH can deliver;
C: % of all items the WH has in stock.

In the previous example, using the DR to choose the WH to fulfill order #1:

	WH1	WH2
A	1	0.8
B	1	1
C	0.5	1
DR3	2.0	2.8

The WH that minimizes DR is WH1, thus the **DR was able to capture the aforementioned trade-off!**



Possible improvement over a policy that assigns orders minimizing the immediate cost

Improvement achieved by the example's DR (one of the best found)

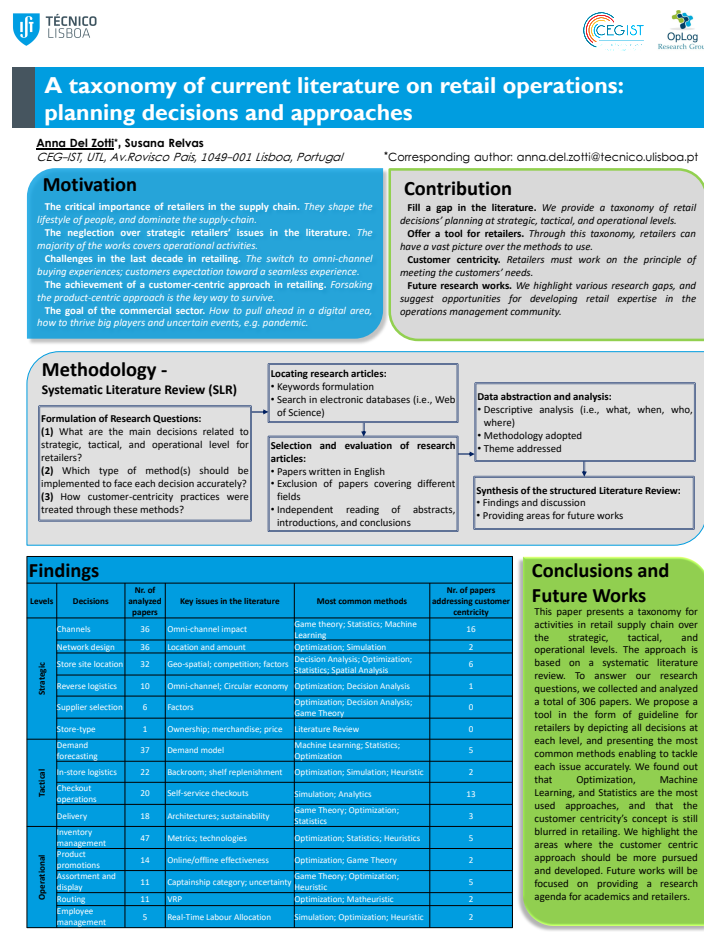
Submissão #42

A taxonomy of current literature on retail operations: planning decisions and approaches

Anna Del Zotti, Susana Relvas

Retailers must embrace a customer-centric approach over operations in the retail supply chain to compete and endure effectively in the current disrupted digital market. Thus, they must be agile and forward-thinking in the use of relevant methods to make suitable decisions and address ongoing difficulties. This work aims to (1) provide a taxonomy of current literature on retail decisions' planning at the strategic, tactical, and operational levels; and (2) review trends and directions of approaches to address the above decisions towards the achievement of customer-centricity and decision compatibility across the three levels of planning in the retail supply chain. The current work is based on a categorization process that emphasizes the importance of managing a retail business as an integrated system, rather than considering each level separately without coordination among levels, by identifying customers' needs and pain points and then developing a solution to sell them, placing the customer at the center of all strategies. Finally, by addressing the limitations inherent in this study, we highlight various research gaps and suggest opportunities for developing retail expertise in the operations management community. To answer our research questions, we collected and analyzed a total of 308 papers.

Keywords: Retail Operations, Retail Supply Chain, Decision Levels, Customer-centric Approach



Submissão #43

Nesting and scheduling for additive manufacturing: an approach considering order due dates

Paulo Nascimento, Samuel Moniz, Cristóvão Silva, Stefanie Mueller

Additive manufacturing (AM) is an emerging production technology that is gaining enormous popularity in manufacturing systems, facing its industrialization phase. However, to adopt this technology, adequate scheduling of the AM machines is critical to guarantee the desired levels of efficiency. AM has unique characteristics such as producing parts with different materials, areas, heights, and volumes in the same building platform, which require integrating nesting (2D bin packing) decisions with scheduling decisions. Moreover, producing different parts simultaneously in the same building platform means that a part inherits the completion time of the assigned batch even if it is completed much sooner. Thus, this paper investigates and proposes a formulation to solve the problem of nesting and scheduling of parallel AM machines, while considering the satisfaction of order due dates. The integration of nesting with scheduling, as well as the consideration of different due dates, are often neglected aspects in the relatively small existing literature on AM scheduling. An example motivated by an industrial case is used to demonstrate the applicability of the proposed formulation and the importance of adequate scheduling of AM machines.

Keywords: Additive manufacturing, Scheduling, Nesting, Bin packing, Mathematical programming, Production planning

Nesting and scheduling for additive manufacturing: an approach considering order due dates

Research funded by 2020 FCT-MPPO330 PhD Grant

Research Team

how to solve nesting and scheduling decisions simultaneously?

How to optimally nest different and irregular parts into jobs?
 A part i assigned to job j inherits the start, processing, and end time of job j , regardless of its characteristics

↓ 2DBPP will affect

- fulfillment of due dates
- production costs

Batch processing machine (BPM) scheduling problem

→

Strongly NP-hard!

→

2D bin-packing problem (2DBPP)

assumptions

- Identical parallel AM machines
- Processing time of job j = Longest processing time of parts in job j
- Setup times are not considered
- All products fit in the AM machine and use the same material and layer thickness
- Due dates can be exceeded by a maximum value, but with a penalty
- A number of jobs is predefined but not all jobs are necessarily used
- Nesting based on the dotted board model with binary variables of Cherri *et al*²

integrated CP model for nesting and scheduling

Relevant parameter
 H_d job where dot d belongs

Binary variables
 X_{id} assign part i to dot d

Interval variables
 T_i tardy job i

B_j interval of time of job j

M_m interval of time of job j in machine m

Sequence variables
 S_m order of intervals in machine m

Objective function
 minimize $(\sum_{i \in I} presenceOf(B_i) * (newjob + sizeOf(B_i)) + \sum_{i \in I} T_i * tardycost)$

Nesting constraints
 $X_{id} = 1 \Rightarrow \sum_{i' \in I, i' \neq i} X_{i'd} = 0$

$\forall i \in I, d \in IFFP_i$

$\sum_{d \in IFFP_i} X_{id} = 1, \forall i \in I$

Scheduling constraints
 $alternate(B_j, M_m), \forall j \in J, m \in M$

$noOverlap(T_m), \forall m \in M$

Relationship constraints
 $sizeOf(B_{id}) \geq p_i * X_{id}, \forall i \in I, d \in IFFP_i$

$startOf(B_{id}) \geq r_i * X_{id}, \forall i \in I, d \in IFFP_i$

$X_{id} = 1 \Rightarrow maxDelay + T_i \geq (endOf(B_{id}) - dd_i), \forall i \in I, d \in IFFP_i$

Other constraints
 Symmetry breaking constraints

promising results for short term planning

Computational time is strongly affected by the number of jobs

Knowing in advance the optimal number of jobs increases the model performance

Symmetry breaking constraints (SBC) work better with more jobs than required

CP quickly finds good quality solutions but takes time to prove optimality

		Instances (2 machines)		
		15 parts 5 jobs	18 parts 5 jobs	20 parts 5 jobs
Time (h)	Find	776	1.229	1.708
	Prove	1.236	13.585	24.749

future steps

Address the computational performance of the CP model

- Adopt a more efficient nesting model with integer variables and the new global constraint of Cherri *et al*² → **63% faster**
- Introduce more symmetry breaking and redundant constraints
- Better and faster instantiation of the model

Future model add-ons

- Consider sequence dependent setup times
- Integrate non-identical AM machines and different AM technologies
- Scheduling by families of products based on the material used and layer thickness

1. Zhang J, Yao X, Li Y. Improved evolutionary algorithm for parallel batch processing machine scheduling in additive manufacturing. *Int J Prod Res.* 2020;58(9):2265-2282

2. Cherri LH, Caravalla MA, Ribeiro C, Toledo FMR. Optimality in nesting problems: New constraint programming models and a new global constraint for non-overlap. *Oper Res Perspect.* 2019;6(10):125

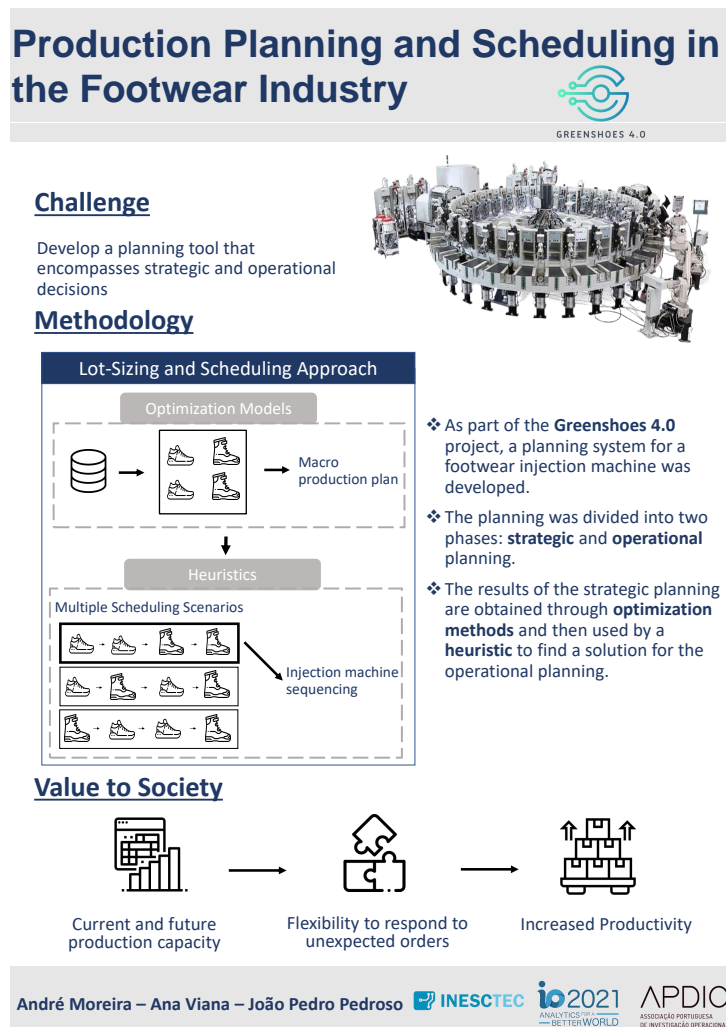
Submissão #44

Production Planning and Scheduling in the Footwear Industry

André Moreira, Ana Viana, João Pedro Pedroso

In recent years, the Portuguese footwear industry has changed drastically. What used to be a low-cost mass production industry has changed to retail chains dealing with small orders and personalized footwear. These changes increase the demand for flexible and fast production lines, able to deliver orders of any size. This paper deals with production planning for the injection line of a company producing safety shoes. In this study, a new method for long/medium-term planning is proposed to balance the production over the following weeks, minimizing the production costs, stocks and backlog requirements. This is complemented with a short-term planning (sequencing) algorithm for dealing with operational requirements. In order to solve both problems simultaneously, a method iterates between the midterm lot-sizing problem and the scheduling a heuristic, adjusting the capacity considered in lot-sizing if the scheduling problem turns out to be infeasible. Results obtained show that the company can significantly benefit from this new planning method.

Keywords: Lot-Sizing, Scheduling, Production Planning



Submissão #45

Desenho de redes para o combate a incêndios florestais

Filipe Alvelos, Susete Marques, Mariana Dias, Isabel Martins

O tempo de resposta a uma ignição é um factor crucial no sucesso do combate aos incêndios florestais. Neste trabalho, propõe-se a construção/operacionalização de uma rede viária que facilite a movimentação de meios para a vigilância, pré-posicionamento e ataque inicial de incêndios florestais. A rede é definida por um conjunto de bases e das estradas que as unem e o seu desenho tem com função garantir que é possível chegar de uma base a qualquer local de uma potencial ignição dentro de um tempo limite pré-determinado ou, não sendo possível chegar a todos, chegar ao maior número de potenciais locais de ignição. Com base em modelos de programação inteira mista que combinam p-localização com caixeiro viajante e com árvore de suporte, analisam-se duas potenciais configurações da rede: em anel e em árvore. Discutem-se diferentes objectivos e a incorporação de incerteza nos locais de ignição. Este trabalho foi realizado no âmbito PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire" financiado pela FCT, Fundação para a Ciência e Tecnologia.

Keywords: Incêndios florestais, Programação inteira mista, Redes, Cobertura



Desenho de redes para o combate a incêndios florestais

Filipe Alvelos (1,2), Susete Marques (3,4), Mariana Dias (3), Isabel Martins (4,5)

Contribuições

- Framework para melhorar decisões numa área de relevância indiscutível
- Integração de problemas de (p-)localização e desenho de redes (caixeiro viajante e árvore de suporte)

Problema geral

- Onde localizar um dado número de bases e que ligações estabelecer entre elas de forma a melhor cobrir um conjunto de locais (destinos)
- Rele tem de ser conexo: entre quaisquer duas bases seleccionadas tem de existir um caminho (árvores de suporte, AS) ou dois caminhos (caixeiro viajante, CV)

Aplicações

- Localização de meios para detecção de ignições e alertas (e.g. postos de vigilância, câmaras térmicas e de imagem)
- Pré-posicionamento de meios de combate para intervenção imediata
- Patrulhamento terrestres / vigilância dissuasiva
- Eficiência na movimentação (e.g. para ataque inicial e recuperação da capacidade de ataque inicial)

Desenho da rede para cobertura

- Bases têm alcance limitado
- Otimização lexicográfica:
 - Cobrir o maior número de destinos
 - Minimizar o comprimento da rede

Desenho da rede para rapidez

- Desenho da rede para o pior cenário (e.g. ignição mais longínqua)
- Ligações da rede 10 vezes mais rápidas que ligações entre bases
- Otimização lexicográfica:
 - Minimizar o maior tempo de chegada a qualquer destino
 - Minimizar tempo médio (arcos da rede são mais rápidos)

Experiências computacionais

- n, p, m – número a definir de potenciais bases e número de destinos
- Instâncias aleatórias (24)
 - pontos gerados aleatoriamente no plano
 - $n \in \{10,20\}$, $p \in \{5,10\}$, $m \in \{10,40\}$
- Instâncias baseadas nas ZIF de Paiva e Entre Dourado e Sousa
 - $n \in \{10,20\}$, $p \in \{5,10\}$, $m \in \{593,677\}$
 - potenciais bases escolhidas por terem a altura maior que todos os locais a dois passos (sem excepções de altura para estas locais mais próximas)
 - distâncias Euclidianas entre bases e destinos, distâncias do caminho mais curto (por conexão) entre bases
- Geobrapy

Conclusões

- Desenho da rede (AS ou CV) não influencia o número de destinos cobertos ou o maior tempo de chegada (como esperado quando apenas esses objectivos são considerados)
- No problema de vigilância, o comprimento de rede é aprox. 70% maior com CV do que com AS (instâncias aleatórias e ZIF) – compromisso com maior extensão e conectividade
- No problema de ataque inicial, a diferença entre tempo médio (AS vs. CV) é sempre <1% ou ZIF vs. em geral, <10% nas instâncias aleatórias
- Nas ZIF a duplicação de p não melhora a solução, mas a duplicação do número de bases candidatas reduz o maior tempo de chegada em aprox. 50% - a definição de localizações candidatas é decisiva para a qualidade da cobertura
- Tempo de optimização dos modelos são aceitáveis (de segundos a meia-hora) para o horizonte temporal da tomada de decisão
- Trabalho futuro: aprofundar modelação com dados reais

(1) Algoritmi, Universidade do Minho, (2) Departamento de Produção e Sistemas, Universidade do Minho, (3) Centro de Estudos Florestais e Laboratório TERRA, Universidade de Lisboa, (4) Instituto Superior de Agronomia, Universidade de Lisboa, (5) Centro de Matemática, Aplicações Fundamentais e Investigação Operacional, Universidade de Lisboa

Trabalho financiado pela Fundação para a Ciência e a Tecnologia no âmbito do projecto PCIF/GRF/0141/2019, An Optimization Framework to reduce Forest Fire



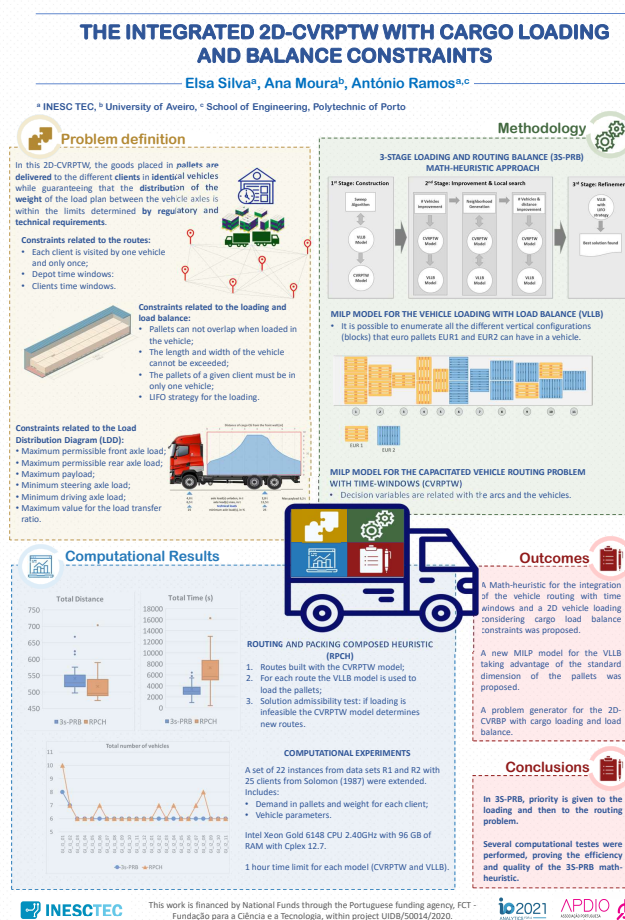
Submissão #46

The integrated 2D-CVRPTW with cargo loading and balance constraints

Elsa Silva, Ana Moura, António G. Ramos

This work integrates the capacitated vehicle routing problem (VRP) with time windows and the 2D loading problem with balance constraints. The goods placed in pallets are delivered to the different clients in identical vehicles while guaranteeing that the distribution of the weight of the load plan between the vehicle axles is within limits determined by regulatory and technical requirements. Implementing new regulatory and technical requirements for the distribution of vehicle axle weights in road freight transport places a new set of constraints on VRP. The load plan in the freight transport units has been neglected in determining the routing of vehicles, which acquires greater importance since non-compliance with the axle weight distribution legislation translates into heavy fines. A three-phase math-heuristic is proposed to generate cargo loading plans and routing sequences of a palletised cargo distribution problem. The math-heuristic gives greater importance to the loading problem, and then to the VRP. Moreover, a new MILP model for the 2D pallet loading problem with balance constraints taking advantage of the standard dimension of pallets is proposed. Extensive computational experiments were performed with well-known literature benchmark instances extended to incorporate additional features. The computational results show the effectiveness of the proposed approach.

Keywords: Vehicle Routing Problem, Vehicle Loading Problem, Load Balance, Math-heuristic




Submissão #47

Cross-docking in-house operations: a simulation-optimization approach


Fábio Coelho, Susana Relvas, Ana Barbosa-Póvoa

The need for companies to have extremely efficient and flexible distribution facilities makes in-house logistics operations complex in a just-in-time context. Thus, to reach the desired levels of efficiency for their companies, decision-makers need to be equipped with decision support tools to help them manage their in-house logistics operations. In this way, a decision support tool based on an optimization-simulation approach is here developed to explore in-house logistics operations. Several scenarios are analysed in order to study these operations with the objective of finding possible sources of congestion and identify improvements. The developed tool was applied to a real-based case of a cross-docking facility, and the results show possible improvements in the system through the optimization of in-house logistics operations.


Keywords: simulation-optimization, in-house logistics, cross-docking, warehouse



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Simulation-optimization tool for cross-docking in-house operations

Fábio Coelho^a, Susana Relvas^a, Ana Barbosa-Póvoa^a
^aCEG-IST, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal
^{*}Corresponding author: fabio.coelho@tecnico.ulisboa.pt

Introduction

Goal

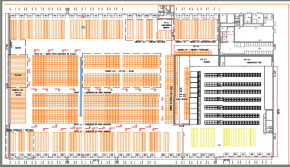
- Develop a decision supporting tool based on a simulation-optimization approach that will allow to analyse the in-house logistics systems of a just-in-time distribution centre to improve competitiveness and support company's value-added processes.

Concepts:

- A traditional distribution centre has four major functions, namely receiving, storage, picking and shipping.
- Storage and picking are the costliest activities and by reducing these two activities, just-in-time distribution centres enable cost reduction;
- Allowing customers to customize their products, leads to the need of having both flexible and adaptable in-house logistics systems.

Problem description

The distribution centre under study has a fixed layout, see Figure below, and consists of humans, forklifts, cobots, products, storage locations and empty pallets/bins to collect the products.

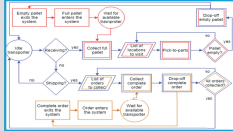


Models

Objective function of the optimization model
 (objective: min. distance travelled)

$$\text{Min} \sum_{i \in I} [\text{distPcb}_{c_i} \times NV_{c_i} \times (1 - ppb) + \text{distPpb}_{c_i} \times NV_{c_i} \times ppb] + \sum_{f \in A} \sum_{s \in S} [\text{distS}_f \times x_{s,f} \times PS_f]$$

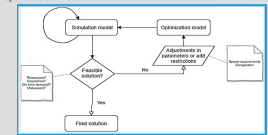
Activities cycle diagram of the simulation model



Simulation-optimization approach

The simulation-optimization decision support tool consists of the iterative use of both optimization and simulation models to address the in-house logistics optimization of a distribution facility. The general methodology structure is shown in the figure.

- Phase 1:** the optimization model is formulated to achieve an optimal solution for in-house logistics operations;
- Phase 2:** the dynamic component of the problem is simulated to assess the feasibility of the solution (given by the optimization model).
- Phase 3:** if the solution is infeasible (regarding resources, capacities, on-time demand, and/or makespan) it is necessary to make some adjustments in parameters or add some restrictions and return to the optimization model.




Results

	Optimized (B)		Optimized plus congestion/safety restrictions (C)		
	As is (A)	1 st iteration	2 nd iteration	3 rd iteration	3 rd iteration
Average total distance travelled (Km/month)	27030	24557	24983	25342	infeasible
Average makespan (hours/month)	587.4	562.5	550.2	573.0	infeasible


$\lambda=3; \Delta=1$ $\lambda=2; \Delta=1$ $\lambda=1; \Delta=1$
 $\Delta=3; \lambda=1$ $\Delta=2; \lambda=1$ $\Delta=1; \lambda=1$

Main conclusions

Performance increases when congestion and safety restrictions are considered. However, when they become more restrictive, performance decreases. The proposed methodology iteratively achieves an efficient solution, regarding resources, capacities, on-time demand, and makespan to optimize in-house logistics operations.



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Acknowledgements

The authors gratefully acknowledge the financial support from Portugal 2020 framework, under the project POCI-01-0145-FEDER-016418 financed by EU/FEDER through the programme COMPETE2020.


Submissão #48

Supply Chain Resilience considering uncertainty and sustainability


João Pires Ribeiro, Daniel Santos, Ana Barbosa-Póvoa

The COVID-19 pandemic brought many changes to how people and companies operated. Much of the strain caused was unpredictable, and to some extent, with consequences few have foreseen. This reality brought a spotlight to Supply Chain Resilience (SCR) and its importance to a stable and prosperous society. This unpreparedness meant that companies had to adapt their operations on the fly, without any actual preparation, which led to the success of some and the failure of others. Concepts used in SCR as redundancy and flexibility are tools that could have been useful. However, it proved to be far from a universal approach due to the intricate operations of modern supply chains (SC). Moreover, the scarcity of resources and the trade-off towards maximum profitability under steady-state conditions turns the effort of designing and planning a SC into a challenging task. Here, we present our work that combines SC Resilience challenges; SCR metrics, disruptive scenarios modelling and sustainability. We use a novel SCR metric to compare different solutions, a scenario tree with the relative likelihood of disruptions and robust optimization in the price of CO₂ to prepare a SC for Resiliency while keeping with the overall objective of being profitable and satisfying the client demand. Our results show that strategic decisions of Supply Chain Management are crucial for SCR and that the cost of CO₂ can have a meaningful impact in SC, urging decision-makers to act promptly to prepare for the future.


Keywords: Supply Chain Resilience, CO₂, Uncertainty, Disruptions



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#48 **Supply Chain Resilience considering uncertainty and sustainability**
 João Pires Ribeiro* (pires.ribeiro@tecnico.pt), Daniel Santos*, Ana Barbosa-Póvoa*
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Abstract

The COVID-19 pandemic brought many changes to how people and companies operated. Much of the strain caused was unpredictable, and to some extent, with consequences few have foreseen. This reality brought a spotlight to Supply Chain Resilience (SCR) and its importance to a stable and prosperous society. This unpreparedness meant that companies had to adapt their operations on the fly, without any actual preparation, which led to the success of some and the failure of others. Concepts used in SCR as redundancy and flexibility are tools that could have been useful. However, it proved to be far from a universal approach due to the intricate operations of modern supply chains (SC).

Objectives

- Design and Planning of a SC considering the trade-off between maximum profitability under steady-state and resilience capabilities.
- Our work combines SC Resilience challenges; SCR metrics, disruptive scenarios modelling and sustainability.
- Study the impact of uncertainty in resilient SC, namely the variability in the prices of CO₂.

Highlights

- We use a novel SCR metric to compare different solutions, a scenario tree with the relative likelihood of disruptions and robust optimization in the price of CO₂
- This approach allows to build a resilient SC while keeping with the overall objective of being profitable and satisfying the client demand.
- Our results show that strategic decisions of Supply Chain Management are crucial for SCR and that the cost of CO₂ can have a meaningful impact in SC, urging decision-makers to act promptly to prepare for the future.

Introduction

Customer Demand

- Meeting demand under disruption
- Brand value at risk

Disruptions

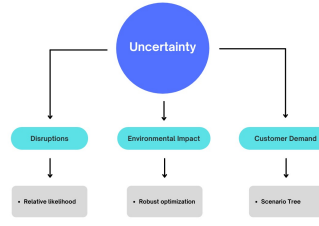
- Unforeseen events
- Unknown probabilities and consequences

Environmental Impact

- Higher costs with CO₂
- Customer awareness
- Climate change

Financial Sustainability

- Endanger company
- Trade-off resilience and investments



Robust Optimization approach for the CO₂ Cost per time period

Uncertainty set U presented below follows the cardinality-constrained approach of Bertsimas and Sim (2004).
 The cost C_{it} is uncertain in an interval $[\underline{C}_{it} - \delta_i, \overline{C}_{it} + \delta_i]$
 \underline{C}_{it} is the nominal (or deterministic) value; δ_i is the maximum allowed deviation; F is the budget of uncertainty that controls how many of the uncertain parameters can deviate from their nominal value

$$U = \left\{ C_{it} \in [\underline{C}_{it} - \delta_i, \overline{C}_{it} + \delta_i], \forall t : \sum_{i \in I} \frac{|C_{it} - \underline{C}_{it}|}{\delta_i} \leq F \right\}$$

Case Study

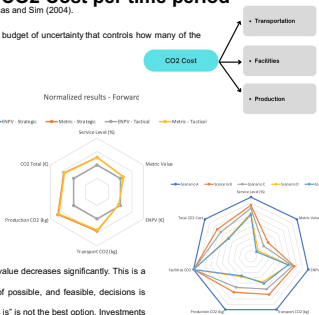
Strategic and Tactical level decision.
European SC, with possible expansion to current SC.

Main decision variables:

- Facilities opened
- Expansion to SC capabilities
- Flows between entities
- Production levels
- Inventories level

So as to:


- Maximize Expected Net Present Value
- Maximize the SC Resilience Metric
- Minimize environmental impact
- Provide insights on how to build a more resilient SC




Results

Maximizing the resilience metric instead of ENPV leads to similar ENPV values with significant changes in the other KPI, namely higher service level. The investment in the satisfaction of demand does not correspond directly to the reduction in ENPV. Allowing the decisions on the flows to open to happen every scenario (from strategic to tactical decision level), bring no clear benefit, leading to a small reduction in emissions. Variations on the price of CO₂ has a significant impact on the results. Notably the metric value decreases significantly. This is a result of the difficulties in meeting demand without aggravating too much the costs. As the prices increase there is less difference between the solutions since the space of possible, and feasible, decisions is smaller. Seems to indicate that just responding to CO₂ costs and disruptions with the operation "as is" is not the best option. Investments in lower emissions should be considered. CO₂ costs are around 34% of ENPV

Resilience Metric maximization: Scenario A - Prices Constant (0.0271), B - Delta 1=0.02, 2=0.04, 3=0.05, C=1=0.04, 2=0.05, 3=0.05, D=1=0.05, 2=0.04, 3=0.07, E=1=0.05, 2=0.04, 3=0.07



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Figueira da Foz, 7 e 8 de novembro de 2021




Submissão #49

Monetization Methods for the Design and Planning of Green Supply Chain

Cátia da Silva, Ana Barbosa-Póvoa, Ana Carvalho

The need to comply with environmental requirements has become a growing issue in supply chains. Nowadays it is not enough to achieve strong financial outcomes, but also to respond to environmental practices that are required for a better companies' sustainable development. Additionally, the environmental decisions are not easy to take due to the difficulties associated with its quantification and understanding by decision-makers. In this way, the quantification of the environmental impacts in a monetary unit easily understood by decision-makers can effectively simplify the decision-making process. However, there are no studies that address how different environmental impact monetization methods can influence supply chain performance. This study explores how different monetization methods may influence supply chain design and planning. To do that a mixed-integer linear programming model is developed for the design and planning of supply chain that accounts for economic and environmental goals. The three main monetization methods are characterized and used to model the environmental supply chain performance. The model is applied to a set of case studies. As main conclusion, this work contributes to understanding the behaviour of each monetization method and what are the main differences in supply chain performance, related to supply chain design and planning.

Keywords: green supply chain, monetization, design and planning, sustainability

Monetization Methods for the Design and Planning of Green Supply Chain

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Introduction

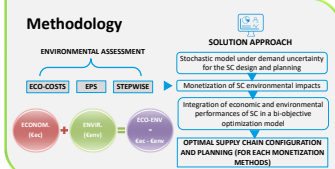
- Stakeholders intend to improve their SC environmental and social performance, while optimizing their economic performance → **Multi-objective optimization methods**;
- The appropriate **weighting of those objectives remains as an issue to be solved** (Lim et al. 2013);
- Decision-makers are used to deal with monetary units when managing their SC → **Translate supply chains' impacts into monetary units**;
- Knowing the **high availability of monetary valuation methods** → Difficulty in understanding which method best suits in a supply chain context;
- To help decision-makers, it is necessary to understand **how different environmental impact monetization methods can influence the supply chain performance**.

Objectives

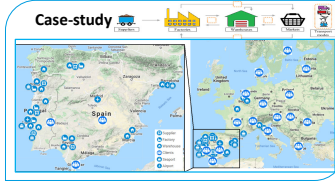
- Perform a **monetization of environmental impacts** of a real SC;
- Understand the **methodological basis** of the main monetization methods;
- Systematize and compare the **most appropriate monetization methods** in the supply chain context;
- Analyze the **behavior of each method** and verify the main differences in SC performance and superstructure.

HOW CAN DIFFERENT ENVIRONMENTAL MONETIZATION METHODS INFLUENCE AND SUPPORT THE DECISION-MAKING PROCESS?

Methodology

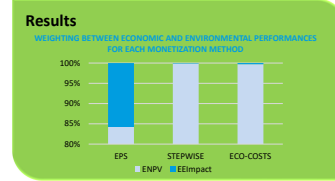


Case-study



Results

WEIGHTING BETWEEN ECONOMIC AND ENVIRONMENTAL PERFORMANCES FOR EACH MONETIZATION METHOD



Results

SC SUPERSTRUCTURE FOR EACH MONETIZATION METHOD



	EPS 2015	STEPWISE 2015	ECO-COSTS 2015
Allocation of suppliers	3 suppliers in Portugal plus 2 suppliers in Spain	1 supplier in Portugal plus 2 suppliers in Spain	3 suppliers in Portugal plus 1 supplier in Spain
Factories	3 factories in Portugal plus 1 factory in Spain	2 factories in Portugal plus 2 factories in Spain	3 factories in Portugal plus 2 factories in Spain
Warehouses	2 warehouses in Portugal, 2 warehouses in Spain, 1 warehouse in France, 2 warehouses in Italy and 1 warehouse in Belgium	All possible warehouses are used (including a central warehouse)	All possible warehouses are used (including a central warehouse)

Technologies: When opening new factories, alternative technology is preferred.
EPS encompasses more impact categories than STEPWISE and ECO-COSTS. Also, EPS includes more SC classes' concerns, i.e., human health and resources concerns.

Conclusions

- This work contemplates both economic and environmental performances in the same objective function;
- The choice of the environmental monetization method influences the structure of the SC network and planning;
- The monetization methods allow an easier understanding of environmental impacts → Translated into a usual unit for decision-makers.

Acknowledgements
The authors acknowledge the support provided by FCT and PORTUGAL2020 under the project PTDC/EGE-OGE/28871/2017, Lisboa-01.0145-Feder-28071

Submissão #50

3D intelligent pallet loading algorithm for crossdocking automation

Pedro Rocha, António G. Ramos, Elsa Silva

The current challenge tackles the implementation of an automated mixed-palletizing cross-docking system, focusing on generating online 3D packing patterns with highly compact, stable, and safe pallet configurations. This improves the efficiency of the containerization and transportation process, which contributes to an improved service level. In the literature, this problem is described as 3D-CLP and is common in supply chains and industries where cargo transportation inside a container is required. Most research related to 3D-CLP focuses on volume optimization, while real-world applications require additional constraints to be tackled, such as stability and balancing for item damage mitigation during assembly and transportation, and also operational safety during loading and unloading operations. Additionally, there is a lack of research considering real-time (online) packing of the items (especially when no information exists about their arrival order, time and sequence, and palletization need to be done as soon as they are available). This problem is created by real world transportation lead-time variability, which disrupts the planned scheduling by delaying or anticipating the reception of the items, causing a decrease in the service level (among other metrics). Due to the complexity of this problem, the most viable approach consists of the use of heuristics.

Keywords: 3D Container Loading Problems, Online Palletization, Cutting and Packing problems

3D Intelligent Pallet Loading Algorithm for Crossdocking Automation

Authors: Pedro Rocha¹, António Ramos^{1,2}, Elsa Silva¹
Affiliation: ¹INESC TEC, ²School of Engineering, Polytechnic of Porto

Overview

- Implementation of an **automated mixed-palletizing cross-docking system**, focusing on generating **online 3D packing patterns** with highly compact, stable, and safe pallet configurations, improving the efficiency of the containerization and transportation process, which contributes to an improved service level.

Supply Chain Information and Product Flow

Stores place orders to HQ → HQ requests supplies to factories → Factories deliver products to warehouse → Warehouse delivers palletized assortment to stores

Warehouse Crossdocking Automation System

- Due to **real world transportation lead-time variability**, the **planned scheduling** is constantly **disrupted** either by **anticipating or delaying the reception of items**
- Items are stored in the warehouse until orders are ready to be fulfilled, or 80% of the items are in stock and the remaining will arrive during construction
- Robots will **build the mixed item pallets** considering the computed **3D mosaic**

Online 3D-CP (Mosaic) Builder

- Real-world applications** require tackling **multiple constraints** (beyond volume optimization)

Challenges

- Stability and balancing
item damage mitigation during
assembly and transportation
- Operational stability
during loading
and unloading operations

Objective

- Minimize Total Pallets Used
- Maximize Occupied Volume

Constraints

- Weight
- Height
- Item Stability
- Item Load
- Item Orientation

Benefits

- Improved service level, transportation efficiency** (more cargo, fewer vehicles, faster deliveries), **cost savings**, reduced consumption of **resources and energy**, among others.

This work is co-financed by the ERDF – European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation – COMPETE 2020 under the PORTUGAL 2020 Partnership Agreement, and through the Portuguese National Innovation Agency (ANI) as a part of project “TPOC-GI-01/2020-030895”

Submissão #51

The multi-period vehicle routing problem with refueling decisions

Fábio Neves-Moreira, Mário Amorim-Lopes, Pedro Amorim

Surprisingly, most vehicle routing approaches disregard the need to refuel the fleet during the considered planning horizon. However, refueling operations may impact vehicle routes, affecting travelled distance and transportation cost. In this work, our main goal is to provide managerial insights on the impact of considering refueling operations in multi-period vehicle routing problems. To efficiently find solutions, we propose a novel mathematical formulation, which is solved by both a branch-and-cut algorithm and a matheuristic approach. The computational experiments on a new set of randomly generated instances demonstrate that the branch-and-cut converges to the optimal solution in single-vehicle instances and that the matheuristic achieves an average optimality gap that is below 7% for the whole set of instances. Furthermore, we perform a sensitivity analysis on several fuel-related parameters. Results indicate that, to minimize costs, the percentage of detour distance may increase up to 6 percentage points when fuel stations with lower prices are further from the depot. The importance of considering a multi-period horizon in this vehicle routing problem is also analysed. For practice, these insights imply that current policies disregarding the location and/or price of fuel stations along with "myopic" planning horizons may lead to sub-optimal decisions.

Keywords: Transportation, Vehicle routing, Refueling decisions, Branch-and-cut, Matheuristic, Managerial insights


XXI Congresso da Associação Portuguesa de Investigação Operacional, 7-8 November 2021

On the impact of refueling decisions in multi-period vehicle routing problems


Fábio Neves-Moreira** Mário Amorim-Lopes** Pedro Amorim**

There is a huge price differential between fuel prices of Portugal and Spain!


1.53 €/L




≅ 0.27 €



1.26 €/L



What can we do? 

Problem description


Objective
Use a set of vehicles to serve the demand of a set of customers through a finite planning horizon composed by a set of periods, while minimizing the total refueling cost.

$$\text{minimize } \sum_{k \in K} \sum_{h \in S} \sum_{t \in T} p_{s,t}^k$$


Parameters
 Upper Limit U^k , Lower Limit L^k , J^k Initial Fuel Level, $P_{s,t}$ Fuel Price, D_i^t Demand, C^k Vehicle Capacity, $A_{i,j}^t$ Arc Fuel Consumption, Depot

Solution approach

2 solution methods



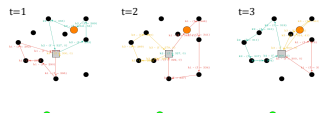
Branch-and-cut algorithm (B&C)



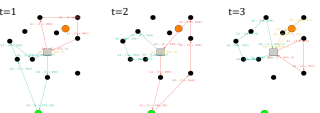
Fix-and-optimize matheuristic (F&O)

Illustrative example

Cheap fuel is 10 cents less
(vehicles opt for fuel stations located nearby)



Cheap fuel is 50 cents less
(vehicles travel larger distances to refuel at lower price)



Legend: ■ Depot, ● Customer, ● Normal price fuel station, ● Cheap price fuel station

Managerial insights on refueling decisions

Results consider only instances solved to optimality

Refueling Cost (€)

330.5	355.4
269.1	296.3
210.3	232.2

Detour Distance (Km)

40.4	48.7
40.1	83.2
106.8	126.2

% cheap station visits

100%	100%
100%	55%
100%	88%
100%	100%

CheapsNear CheapsFar Price differential Graph layout

1. When cheap stations are nearby, vehicles do not visit normal priced stations.
2. The detour distance and cheap station visits increase with the price differential.
3. The impact of adding more fuel stations to the graph is not big.

Be careful! Opportunities to refuel at lower price may lead to less sustainable solutions!

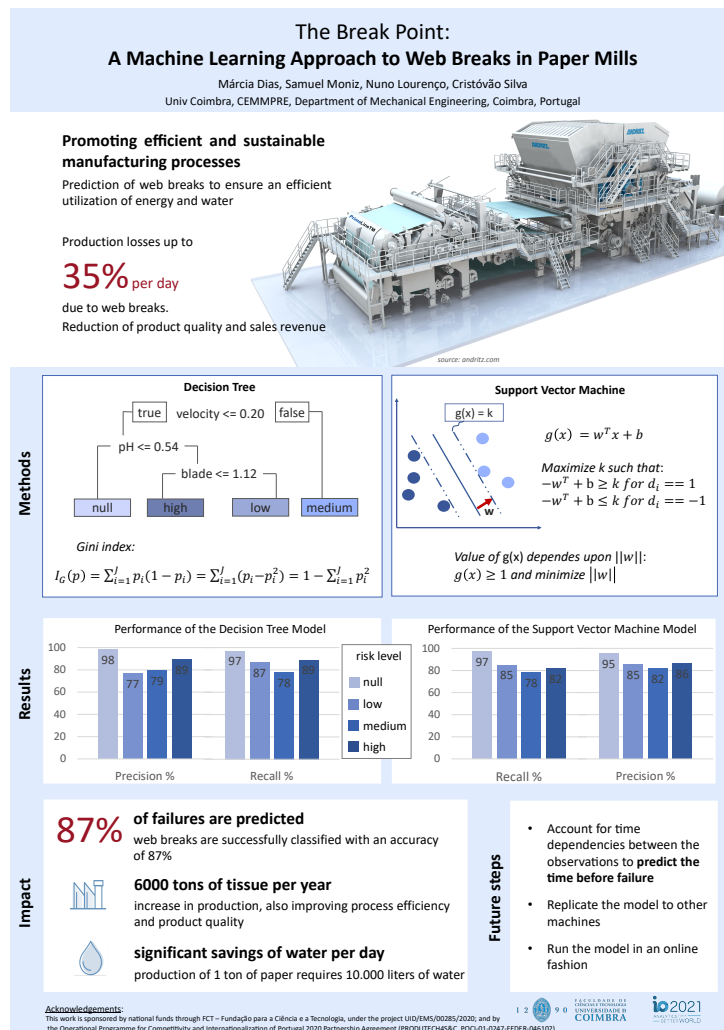
Submissão #52

Identifying and predicting web breaks in a tissue machine: a machine learning approach

Marcia Dias, Samuel Moniz, Nuno Lourenço, Cristóvão Silva

Web breaks are a significant operational challenge of the paper industry, which affect process efficiency and product quality. This work aims to develop and validate a machine learning approach to predict the risk of web breaks in tissue machines, in real-time. Firstly, we select a reduced set of variables to avoid data unavailability and sensor errors. Secondly, we use data segmentation to define web break trajectories and risk levels, which helps in identifying failure patterns. Lastly, we develop a prediction model to find patterns during the regular operation of the machine. To validate the approach, we applied it to a large-scale industrial problem. Results show that the model effectively predicts web breaks with an accuracy of 87%, reducing production losses by up to 6000 tons of paper per year. These results corroborate the contributions of the proposed approach, namely: i) the developed variable selection scheme can effectively translate a very complex manufacturing system into a reduced set of variables; ii) the procedure uses production data to support effective decisions that leverage the productivity of recent and technologically advanced tissue machines; and iii) the comprehensive data-driven procedure copes with the increasing pressure to increase the production efficiency of continuous production environments.

Keywords: decision trees, machine learning, paper industry, prediction model, web breaks



Submissão #53

Optimizing monitoring equipment investment for an asset portfolio with multiple-failure modes

Luis Dias, Armando Leitão, Luis Guimarães

In many industries, asset portfolio condition degradation is stochastic and subjected to multiple failure modes, negatively impacting asset availability and longevity. To minimize this impact, recent technological advances in monitoring technology may foster a reduction in degradation uncertainty and prevent asset failures. Notwithstanding, the extra effort regarding the investment plan on this type of equipment must be carefully planned. Since investing in monitoring equipment requires substantial capital due to the system size, DMs must define which and when a given asset monitoring technology will be installed. Hence, not every asset may have the same monitoring technology and, consequently, the same degradation uncertainty. Bearing this in mind, we propose a methodology to determine the investments in the installation of monitoring equipment for an asset portfolio with multiple failure modes and maintenance budget constraints. The goal is to optimize the cost of reducing the asset degradation uncertainty and maintenance costs without exceeding the available budget. We formulate the problem as a stochastic optimization problem to capture the uncertainty in the assets' condition. The approach is validated in a case study in the electricity distribution in which a system operator must manage a portfolio of power transformers operating under different operational conditions.

Keywords: Multi-unit system, Predictive maintenance, Stochastic optimization, Mixed-integer models, Multiple failures modes

Optimizing monitoring equipment investments for an asset portfolio with multiple failure modes

The challenge

Which monitoring equipment to install?

- More accurate prediction
- More expensive
- Less accurate prediction
- Less expensive

How to model the effect of failure mode 2 on failure mode 1?

Main decisions and constraints

- The monitoring equipment accuracy depends on the failure mode
- The monitoring equipment has heterogeneous accuracy and costs
- An asset failure increases the degradation of nearby assets
- The short-term condition influences the long-term condition

Proposed approach

- Continuous degradation with competing failure modes subjected to random shocks
- Mathematical model to estimate each asset remaining useful life (RUL)
- Continuous imperfect inspection for continuous degradation units
- Power transformers portfolio real-world case study

Contributions

- Integration of competing soft failure modes with continuous imperfect inspection monitoring
- Novel mathematical formulation for the tackled problem
- Obtained relevant managerial insights from a real-world case study

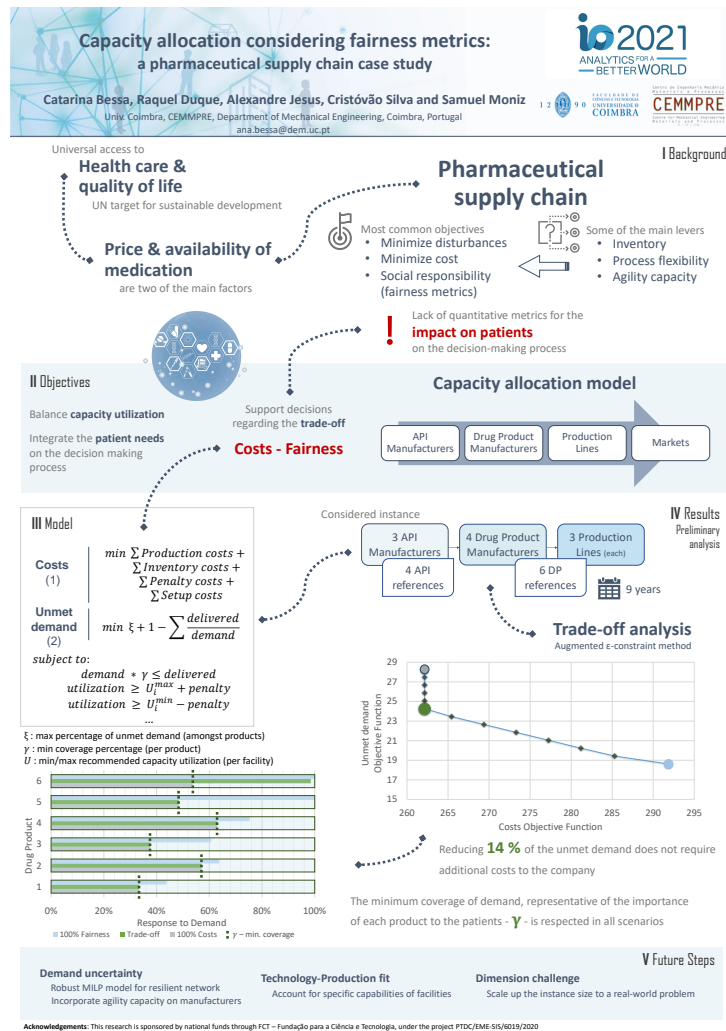
Submissão #54

Capacity allocation considering fairness metrics: a Pharmaceutical Supply Chain case study

Catarina Bessa, Raquel Duque, Alexandre Jesus, Cristóvão Silva, Samuel Moniz

Most drug shortages are related to Pharmaceutical Supply Chain (PSC) vulnerabilities that occur in several production stages. This work seeks to improve the efficiency and sustainability of global pharmaceutical networks by proposing a capacity allocation model that includes fairness metrics to balance the response to patient needs with economic goals. A four-tier supply chain deterministic model, inspired by the literature, is developed to include quantitative metrics that quantify the patient's point of view. To ensure the validity of the proposed approach, the model was verified with real data collected from a leading pharmaceutical company. Furthermore, the results give important insights on optimal product allocation, inventory, and reserved capacity within the supply chain.

Keywords: Capacity Allocation, Mathematical Programming, Supply Chain Management, Fairness Metrics



Submissão #55

The art of the deal: Machine learning based trade promotion evaluation

David Viana, Beatriz Brito Oliveira

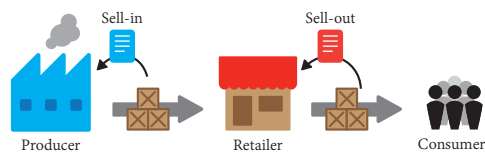
Trade promotions are a complex marketing strategy to drive up sales, involving retailer and consumer dynamics. Furthermore, these events are time-sensitive, influenced by past promotions and both competitor initiatives and responses. In the Consumer Packaged Goods (CPG) sector, the proportion of price-promoted sales to regular-priced sales has increased to a very significant level. Given their relevance to the manufacturer's revenue, proper promotional planning is crucial. In this context, this work proposes a decision support system capable of evaluating a hypothetical trade promotion's success, based on historic data, to be used for the promotional planning process of two key product lines of a CPG manufacturer. At the core of this decision support system, a predictive model, based on machine learning algorithms, will leverage both time series data and predictor variables, in order to better predict future promotional performance. This work pulls from many different branches of knowledge namely, Marketing, Economics, Forecasting, Machine learning and Data mining, areas which are briefly introduced.

Keywords: Forecasting, Promotion planning, Retail



The art of the deal: Machine learning based trade promotion evaluation

David Branco Viana Beatriz Brito Oliveira



Can a producer better negotiate trade promotions with retailers if data he has access to is well leveraged?

Context

The work focuses on the portuguese market, specifically the olive oil and vegetable oil categories.

The recent rise in promotional frequency and intensity translates into higher promotional margins for both the company and the retailer.

Solution

A decision support system was built such that the company's commercial team could simulate and plan promotional scenarios, as well as register and analyse past promotions.

The company had various years' worth of promotion records, a key enabler of the work done, as well as limited records of competitor promotions.

Two types of gradient boosting machine models were trained to predict the average daily liters sold of a product during a given promotion, using available sales data and the basic features of the both the product involved and said promotion.

α-type

- Features and hyperparameters were selected automatically
- Left out features such as discount percentage, leaving the model unresponsive to user changes.
- Gave poorer feedback to the user, diminishing its overall trust in the system.
- Relied heavily on the feature "average daily sales of a product", which made the estimates more conservative.

β-type

- Features and hyperparameters were carefully selected using a mix of expert advice and validation results.
- More sensitive to user changes, by including some nonpredictable features such as discount percentage and month.
- Performed better overall on all three key metrics.

Results

The models were trained for both retailer A, for which both sell-in and sell-out data were available, and for retailer B, for which only sell-in data was available. When using its sell-in data, retailer A is referred to as retailer A*.

Metrics	Olive oil			Vegetable oil		
	Retailer A	Retailer B	Retailer A*	Retailer A	Retailer B	Retailer A*
MAD	0.26	0.20	0.23	0.23	0.20	0.17
MAPE	28.26	35.81	31.27	26.94	26.61	26.99
BIAS	18.15	22.48	16.17	20.44	19.10	15.20
σ ²	1.76	2.08	1.67	1.81	1.75	1.68
WMAPE	14.69	21.41	13.00	12.52	12.24	11.65
WRMS	0.66	1.01	0.62	0.72	0.76	0.67

Metrics	Olive oil			Vegetable oil		
	Retailer A	Retailer A*	Retailer A**	Retailer A	Retailer A*	Retailer A**
MAD	0.20	0.25	0.29	0.24	0.29	0.34
MAPE	23.68	27.40	30.78	26.78	30.50	33.50
BIAS	24.61	4.17	31.20	24.28	11.36	17.61
σ ²	1.03	1.04	1.11	1.03	1.04	1.11
WMAPE	21.45	11.59	11.16	17.61	11.16	10.64
WRMS	1.01	0.67	0.67	0.67	0.67	0.67

Table 2: β-type model metrics for retailer A and retailer A*.

Key takeaways:

- α-type models perform better overall.
- For predicting promotional performance, sell-out data is superior to sell-in data.
- The difference in model performance between the two product categories may be due to different levels of competitor presence, a phenomenon which the models do not adequately capture since the company has a more dominant position in the vegetable oil market, this phenomenon is less prevalent and therefore has a lesser impact on the performance of a promotion.

Using sell-out data instead of sell-in data greatly improves prediction quality. Producers should seek access to sell-out data to better fuel their predictions.



Submissão #56

Improving the production process in a bakery industry: a simulation approach

Fabiane K. Setti, Carla A. S. Geraldes, João P. Almeida, Marcelo G. Trentin

The present study brings forward a simulation-based study of the production process of a Portuguese company that produces a wide range of bread. The main objective of this study was to analyse the different production processes of the company, and to propose further improvements to these, through the use of discrete event simulation. A relevant set of data was collected and four productive processes were chosen to be modelled using the Simulation Modelling based on Intelligent Objects software (Simio). The analysis of the developed models identified the need for improvements and different scenarios were created to this purpose. Among the obtained results, the creation of different mixed production scenarios allowed the maximisation of the production level while maintaining the current existing resources. The results of this work can be implemented in the company to increase production level without increasing costs since they do not involve the purchase of new equipment. In conclusion, this study highlights the ability of the simulation technique to analyse manufacturing processes throughout the creation of different scenarios providing insights on the production process optimising companies' productive performance.

Keywords: manufacturing process, optimisation, discrete simulation

Improving the production process in a bakery industry: A simulation approach

Fabiane K. Setti | Carla A. S. Geraldes | João P. Almeida | Marcelo G. Trentin

Background

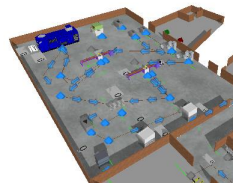
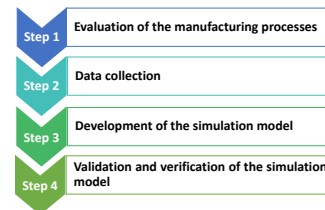


- ✓ Bakery of high quality bread (sourdough fermentation)
- ✓ Large mix of products (different types of bread)
- ✓ Two working shifts:
 - Production daily fresh bread
 - Production of par-baked bread
- ✓ Demand increase causing overtime production

Objectives

- ❖ Analysis of the production processes
- ❖ Improve the current productive processes

Methodology



Modelling and Simulation

Development of 6 Simulation models

- Fig bread
- Wheat bread
- Rye bread
- Bijou bread

35 Scenarios

- Single bread type production
- Mixed-production

Contributions

- Increase of daily production in both working shifts
- Identification of the mix of products that maximizes production output
- It was possible to face the increase of the product demands
- Overtime production was reduced or eliminated

Acknowledgment: This work has been supported by FCT - Fundação para a Ciência e a Tecnologia within the Projects Scope UIDB/05757/2020



Submissão #57

Cálculo de soluções eficientes não suportadas em programação fracionária inteira-mista multiobjetivo

João Paulo Costa, Maria João Alves

Neste trabalho propõe-se uma nova técnica de Branch Cut para calcular soluções não dominadas (eficientes) em programação fracionária linear inteira-mista multiobjetivo, usando pontos de referência. As abordagens de pontos de referência fornecem um meio útil para este cálculo, uma vez que permitem alcançar não apenas soluções eficientes suportadas, mas também não suportadas (ou seja, soluções que são dominadas por combinações convexas não admissíveis de outras soluções não dominadas). Um ponto de referência é uma meta que se pretende alcançar ou mesmo melhorar. Isto implica a otimização de uma função escalar de realização (ASF). A ASF utilizada permite determinar qualquer solução não dominada através da alteração do ponto de referência, garantindo também que apenas se obtêm soluções não dominadas. Infelizmente, o problema transforma-se numa soma de rácios, que é conhecido como um dos problemas não lineares mais difíceis de resolver. Propõe-se, nesta comunicação, uma nova técnica de Branch Cut para este problema. Já existem algoritmos que podem resolver este tipo de problema na prática, desde que não haja variáveis inteiras. Apresentam-se também vários testes computacionais para avaliar o desempenho da técnica.

Palavras chave: Programação fracionária inteira-mista multiobjetivo, Branch Cut, Soluções eficientes não suportadas

Cálculo de soluções eficientes não suportadas em programação fracionária inteira-mista multiobjetivo

João Paulo Costa e Maria João Alves
Universidade Coimbra, CeBER, Faculdade de Economia

Objetivo
Neste trabalho propõe-se uma nova técnica de Branch & Cut para calcular soluções não dominadas (eficientes) em programação fracionária linear inteira-mista multiobjetivo, usando pontos de referência.

Programação Fracionária Linear Inteira-Mista Multiobjetivo

$$\max z_k(x) = \frac{\sum_{i=1}^p c_i x_i + \alpha_k}{\sum_{i=1}^p d_i x_i + \beta_k}, k=1, \dots, p$$

s.t.: $x \in X = \{x \in \mathbb{R}^n \mid Ax \leq b, A \in \mathbb{R}^{m \times n}, b \in \mathbb{R}^m, x \geq 0, x_j \in \mathbb{Z}_+, j \in J, j \in I\}$
 $J, I \subseteq \{1, \dots, n\}, J \cap I = \emptyset, J \cup I = \{1, \dots, n\}$
 $c, d \in \mathbb{R}^n, \alpha, \beta \in \mathbb{R}, d_i, \beta_i > 0, \forall i \in X, k=1, \dots, p, p \geq 2$

Abordagem de Pontos de Referência
Um ponto de referência \bar{z} é uma meta que se pretende alcançar ou mesmo melhorar. Esta abordagem fornece um meio útil para cálculo, uma vez que permite alcançar não apenas soluções eficientes suportadas, mas também não suportadas (ou seja, soluções que são dominadas por combinações convexas não admissíveis de outras soluções não dominadas). Isto implica a otimização de uma função escalar de realização (ASF), que é também uma soma pesada de rácios:

$$\min \left\{ s(\bar{z}, z) = \max_{i=1, \dots, p} \left(\bar{z}_i - \frac{c^i x + \alpha_i}{d^i x + \beta_i} \right) - \frac{\varepsilon}{p} \sum_{i=1}^p \frac{c^i x + \alpha_i}{d^i x + \beta_i} \right\}$$

s.t.: $x \in X$, sendo ε pequeno e positivo

Cálculo do ótimo (eficiente) da função objetivo k

$$\bar{x}_k(x) = \sum_{i=1}^p w_i x_i + \alpha_k - z_k(x) \left(\sum_{i=1}^p d_i x_i + \beta_k \right) + \varepsilon \sum_{i=1}^p w_i x_i + \alpha_k - z_k(x) \left(\sum_{i=1}^p d_i x_i + \beta_k \right)$$

Seja X_k^* o conjunto de soluções que otimiza $z_k(x)$, $x \in X$.
 Se $\bar{z}_k(x^*) = 0$ então $x^*, x^* \in X_k^*$ são eficientes.

Técnica de Branch & Cut

Inicialização:

- Caracterizar a região eficiente do problema através do cálculo da tabela de pay-off. Escolher a solução incumbente a melhor de entre as soluções da tabela de pay-off do acordo com a ASF.

Processo de Branch & Cut:

- Selecionar uma sub-região que ainda não tenha sido subdividida e introduzir cortes em todas as funções objetivo.
- Dividir esta região em duas sub-regiões, impondo restrições.
 - na função objetivo que tiver a maior amplitude de variação, considerando os valores da tabela de pay-off e os cortes introduzidos.
- Calcular a tabela de pay-off das duas novas sub-regiões.
- Atualizar a solução incumbente.
- De entre as sub-regiões ainda não subdivididas ou abandonadas verificar se haverá alguma que pode ser abandonada ou que cumpre a condição de paragem.
- O processo termina quando se houver sub-regiões não subdivididas abandonadas ou que cumprem a condição de paragem.

Condição de abandono
Uma região pode ser abandonada quando o valor da ASF do seu ponto ideal é pior que o valor da ASF da solução incumbente.

Condição de paragem
O processo é repetido para cada sub-região não abandonada e não subdividida até que as sub-regiões restantes sejam mais pequenas do que um erro predefinido, isto é, até que a amplitude de valores de cada função objetivo, na tabela de pay-off, seja inferior ao erro.

O corte
Uma restrição numa função objetivo que retire as soluções cuja diferença entre o valor dessa função objetivo e o da coordenada respetiva do ponto de referência seja maior que o valor da ASF da solução incumbente.

Exemplo

$$\max z_1(x) = \frac{x_1 + 3x_2 + 20}{-2x_1 + x_2 + 14}$$

$$\max z_2(x) = \frac{2x_1 + x_2 + 20}{x_1 - 2x_2 + 14}$$

s.t.:

$$\begin{cases} x_1, x_2 \in \mathbb{Z}_+ \\ 3x_1 + 2x_2 \leq 24 \\ -x_1 + x_2 \leq 40 \\ -x_1 - x_2 \leq 40 \end{cases}$$

	x_1	x_2	z_1	z_2
A	3	7	2.933	12.000
B	4	6	3.500	6.333
C	4	5	3.545	4.625
D	4	4	3.600	3.600
E	5	4	4.625	3.545
F	6	3	7.000	2.929
G	6	2	8.000	2.500

Testes - Multiobjective Multidimensional Knapsack problems

Variáveis binárias

Variáveis inteiras

Variáveis inteiras-mistas

Agradecimento: Este trabalho foi financiado em parte pela FCT, Fundação para a Ciência e a Tecnologia, I.P., Projeto UIDB/05637/2020.

Submissão #58

A análise espacial multicritério na avaliação da aptidão vitivinícola

Sandra Silva, Joaquim Alonso, José Santos, Joana Nogueira

São muitos os fatores e critérios que influenciam as características finais de um vinho. A singularidade dos grandes vinhos terroir é construída com base na combinação de clima, solo e terreno. O conhecimento da zonagem agroecológica e aptidão natural, cultural e económica vitivinícola para a definição e gestão do terroir são condições necessárias de suporte à melhoria do planeamento, dinamização e sustentabilidade dos territórios e unidades de produção vitivinícolas. A avaliação espacial multicritério é uma ferramenta importante de apoio à decisão na definição de uma viticultura de precisão, mais especificamente na definição e análise dos fatores e critérios mais relevantes para avaliação da aptidão natural de um dado local para a produção de vinhos, considerando diferentes perspetivas e saberes multidisciplinares de especialistas.

Palavras chave: Terroir, Apoio à decisão multicritério, Sistemas de Informação Geográfica



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A análise espacial multicritério na avaliação da aptidão vitivinícola

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⁽²⁾ Escola Superior Agrária, Instituto Politécnico de Viana do Castelo

Introdução

São muitos os fatores e critérios que influenciam as características finais de um vinho. A singularidade dos grandes vinhos terroir é construída com base na combinação de fatores naturais como clima, solo e terreno e de fatores humanos, como a cultura e tradição.

Os estudos de zonagem vitícola dividem-se na análise da diferenciação geográfica das características do vinho, da uva ou da videira, e da capacidade ou aptidão vitivinícola (Vaudour e Shaw, 2005). Na **avaliação da aptidão vitivinícola** é necessário definir os parâmetros e critérios a considerar, associar o respetivo nível de importância ou peso para os grupos de interesse envolvidos, considerar a informação georeferenciada envolvida, tendo como objetivo a obtenção de mapas de aptidão. A análise espacial multicritério é assim uma ferramenta importante de apoio à decisão na definição de uma viticultura de precisão.

Este trabalho enquadra-se no âmbito dos Projetos Terr@Alva e Terr@Eno desenvolvidos pelo IPVC.

Motivação

Neste trabalho pretende-se definir os fatores e os critérios mais relevantes para avaliação da aptidão natural de um dado local para a produção de vinhos verdes de qualidade, à escala regional do Alto Minho, em particular das sub-regiões do Lima (casta Loureiro) e de Monção-Melgaço (casta Alvarinho), tendo em conta diferentes perspetivas e saberes multidisciplinares de especialistas, com recurso a métodos de apoio à decisão **espacial multicritério**, para suporte à cartografia de aptidão vitivinícola.

Metodologia

Para tal pretendem-se desenvolver diferentes fases:

- Decidir de forma colaborativa quais são os fatores e os critérios mais relevantes para determinar a aptidão natural de um dado local para a produção de vinhos verdes de qualidade, à escala regional do Alto Minho, tendo em conta diferentes perspetivas e saberes multidisciplinares e especializados (painel de especialistas) sobre o problema/questão;
- Recolher e normalizar os critérios traduzidos em representações espacialmente explícitas, com recurso aos sistemas de informação geográfica;
- Ponderar o peso dos critérios através de um método multicritério adequado (Método de Análise Hierárquica Ponderada - AHP) e integrar por uma combinação linear ponderada espacialmente explícita (WLC);
- Obter os mapas de aptidão;
- Realizar uma análise de consistência aos resultados obtidos e uma análise de sensibilidade;
- Promover a validação dos resultados obtidos pelo mesmo painel de peritos.

FASE 1

Definição de critérios

Seleção de critérios

Hierarquização dos critérios

FASE 2

Bases de dados georeferenciadas

Representação critérios

FASE 3

Método AHP no software QGIS (EasyAHP)

Mapa Aptidão de Solo

Mapa Aptidão de Clima

Mapa Aptidão Agregada

Análise de Sensibilidade

Mapa Aptidão Integrada de Alto Minho

Resultados

FASE 1: Reunião com especialistas da área vitivinícola: produtores, cooperativas, enólogos, académicos.

Definição de critérios e sub-critérios: apresentada uma proposta inicial baseada na bibliografia consultada e em grupo, de forma colaborativa, definiram-se os critérios representando o clima, o solo, a topografia e o terreno. Procedeu-se à estruturação dos critérios de modo hierárquico.

FORÇA GEORREFERENCIADA

- Altitude
- Declividade da propagação lateral de água (riscos)
- Índice de carga Térmica
- Declive
- Tipo de base litológica
- Índice de humidade hídrica
- Unidades geomorfológicas

FORÇA NÃO GEORREFERENCIADA

- Índice Inércia das noites
- Índice Winterler
- Índice Heliotermico de Huglin
- Índice Heliotermico de Bonan
- Precipitação Média Mensal Acumulada
- Empotramento geológico
- Hidrografia
- Índice de consistência de Blau-Martinez
- Índice Heliotermico de Sabatinov
- Índice de Hídrico

FASES 2 e 3: Aplicação do modelo multicritério AHP no QGIS

Os critérios são espacialmente explícitados e normalizados, usando o software QGIS. Cada especialista procede à ponderação do impacto de cada critério, na aptidão natural para a cultura da vinha/produção de vinho verde, relativamente aos restantes, numa comparação a pares, através da atribuição de pesos baseada na escala de Saaty - método AHP (apresentado pela equipa de investigadores).

O método AHP é aplicado com recurso ao software QGIS, ferramenta EasyAHP, por forma a analisar a consistência dos julgamentos e a determinar as prioridades de cada especialista, obtendo-se o mapa de aptidão individual relativo a cada critério, agregados via combinação linear ponderada (WLC).



Junto dos especialistas analisa-se o índice de consistência. Caso não esteja garantida consistência procede-se a uma reanálise e ajuste de pesos. Apresentam-se os mapas de aptidão individual obtidos e descrevem-se uma análise de sensibilidade, por forma a avaliar a robustez da classificação obtida. Por fim, efetua-se a integração dos mapas de aptidão individual obtidos, num mapa final de aptidão vitivinícola.

Discussão e Conclusões

A metodologia apresentada encontra-se na fase de ponderação dos critérios de acordo com a escala de Saaty, por parte de cada especialista. Para melhor expor a metodologia foi considerada a atribuição de pesos de um dos especialistas relativa a um dos critérios, por forma a simular o procedimento na aplicação EasyAHP no QGIS. Apesar de não finalizada, consideramos que a metodologia desenvolvida baseada no apoio à decisão espacial multicritério é a melhor forma de dar resposta à análise da aptidão vitivinícola envolvendo vários critérios, especialistas e informação georeferenciada.



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APDIO

Figueira da Foz, 7 e 8 de novembro de 2021


Submissão #59

Um algoritmo genético para o escalonamento de operações de combate a incêndios

Marina Matos, Ana Rocha, Filipe Alvelos, Lino Costa

A gestão de recursos no combate a incêndios florestais pode ser modelada como um problema de escalonamento de tarefas em máquinas. Nessa abordagem, cada incêndio, ou cada parte de um incêndio, corresponde a uma tarefa que tem de ser processada e cada recurso corresponde a uma máquina. Os tempos de viagem entre diferentes incêndios correspondem a tempos de preparação das operações das tarefas nas máquinas. Um aspeto essencial é que, ao contrário do que acontece na generalidade dos problemas de escalonamento, o tempo de processamento depende do tempo de início do processamento da tarefa. Neste trabalho desenvolve-se um algoritmo genético para obter soluções para este problema. Este trabalho foi realizado no âmbito de PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire" e pela bolsa de doutoramento com a referência UI/BD/150936/2021, ambos financiados pela FCT, Fundação para a Ciência e Tecnologia.

Palavras chave: Incêndios Florestais, Escalonamento, Algoritmo Genético




A genetic algorithm for scheduling firefighting operations

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Introduction

Disasters caused by nature or human action have been increasing in the last decades [3].



In Portugal, on average, about 14000ha burn every year, in more than 22000 forest fires (almost twice the average of other Mediterranean countries), having one of the highest forest fire risk ratings in Europe.

Years	Rural Fires	Stands	Bushes	Agricultural	Total
2010	26257	45777	84391	8223	138391
2011	26127	18831	47704	3825	70160
2012	29237	48022	61229	8829	117010
2013	21917	54905	94564	7168	157327
2014	9095	8701	13889	2954	22544
2015	18945	23461	32638	3796	66796
2016	14980	77390	82595	6260	166185
2017	18945	32863	185611	39669	537143
2018	11450	21873	19114	3091	44728
2019	10528	21411	15831	4000	41850
2020	9394	31803	27824	6200	69887

Several works have been developed to solve the firefighting routes problem, minimizing the total transportation distance and the fire extinction time [3, 4].

Methodology

- Aim:** optimize a sequence of forest fires in order to fight them as quickly as possible.
- How:** - using GA (a stochastic algorithm);
 - using the travel time between the point where the resource is located to the next fire;
 - using processing time used by the resource until firefighting;
 - using completion time for the suppression of fire;
 - computing the unburned area.


This work was based on the papers [1, 2], considering several assumptions present in the cited works.

The problem is to minimize the value of burned area, that is, to maximize the total remaining area value (unburned).

Motivation and Objectives

- Resource management in forest firefighting can be modeled as a machine task scheduling problem.
- In this approach, each fire ignition corresponds to a task that has to be processed, and each resource is equivalent to a machine.
- The travel times between different fire locations correspond to setup times for task operations on machines.
- Unlike in most scheduling problems, the fire propagation time depends on the start time of task processing.

Case Study



Problem Description

subject to

$$V_{ij} = V_{ij}^0 - \alpha_{ij} \left(\sum_{k=1}^i P_{ij}(k) + \sum_{l=1}^j T_{ij}(l) \right) \geq 0$$

where

$$P_{ij}(k) = \begin{cases} \alpha_{ij} t^{(k)} + \gamma_{ij} t + \delta_{ij}, & \text{if } t \leq d_{ij} \\ \gamma_{ij} t + \delta_{ij}, & \text{if } t > d_{ij} \end{cases}$$

for

- α_{ij} integer
- $1 \leq k \leq \alpha_{ij}$
- $X_{ij} = X_{ij}^0$ for $i \neq j$ with $1 \leq i \leq k$

Variable	Description
F_{ij}	Fire ignition $i = 1, 2, \dots, 4$
X_{ij}	Remaining area value (unburned) in fire F_{ij}
V_{ij}	Value of the area at the time when the overall containment effort begins in fire F_{ij}
α_{ij}	Dispatchation rate in each fire F_{ij}
$P_{ij}(k)$	Processing time required from ignition of fire F_{ij}
d_{ij}	Time required for the processor to travel from suppressed fire F_{ij} to fire F_{ij}
$\alpha_{ij}, \gamma_{ij}, \delta_{ij}$	Constant parameters depending on the area near F_{ij} burns (the meteorological conditions, the processor's water, the processor's water capacity and the fire containment area)
$X_{ij}^0, \gamma_{ij}, \delta_{ij}$	Value that depends on the additional resources that will be dispatched to the specific area
d_{ij}	Containment escape time limit

Results

In this study four forest fires are considered, and there are $4! = 24$ possible sequences.

F_i	α_i	β_i	γ_i	δ_i	d_i	X_i	F_{ij}	V_{ij}	T_{ij}		
1	0.46	3.20	0.22	0.005	0.9	0.6	2.0	0.50	154584.25	$T_{1,2} = T_{2,1}$	0.25
2	0.39	3.00	0.24	0.006	0.8	0.6	1.8	0.25	185135.75	$T_{1,3} = T_{3,1}$	0.58
3	1.51	2.70	0.28	0.008	0.7	0.8	1.4	0.40	165585.10	$T_{1,4} = T_{4,1}$	0.83
4	1.50	2.50	0.28	0.009	0.5	1.0	1.0	0.30	111945.84	$T_{2,3} = T_{3,2}$	0.67
										$F_{2,4} = T_{4,2}$	0.33
										$F_{3,4} = T_{4,3}$	0.41






$F_{optimal} = \langle F_2, F_1, F_3, F_4 \rangle$

Conclusions

- Forest fires have increased in the last decades.
- The GA algorithm was able to find an optimal solution in 24 possible sequences of forest fires.
- The best sequence found for the processor to act effectively was $F_{optimal} = \langle F_2, F_1, F_3, F_4 \rangle$.
- This work assists the decision maker in forest fire management when several fires ignite simultaneously.

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Submissão #60

Simulação de incêndios florestais com base no modelo de Rothermel

Catarina Santos, Ana Raquel Xambre, Helena Alvelos, Susete Marques, Mariana Dias, Isabel Martins, João Pedro Silva, João Marques, Senhorinha Teixeira, José Carlos Teixeira, André Mendes, Filipe Alvelos

A forma como o fogo florestal se propaga depende, principalmente, de três factores: combustível (que pode ser caracterizado pela humidade, poder calorífico e carga), clima (nomeadamente a velocidade e a orientação do vento) e o declive do terreno. A incerteza do comportamento ao longo do tempo e do espaço destes factores dificulta a modelação da propagação do fogo. Neste trabalho modela-se essa incerteza através de simulação. A paisagem é representada por uma rede em que os nodos correspondem a células e os arcos à adjacência entre células. Após serem estimadas a velocidade de propagação do fogo (entre células adjacentes) com base na variação de parâmetros do modelo de Rothermel, que permite estimar a velocidade de propagação do fogo de acordo com os factores referidos, utiliza-se a simulação para caracterizar a propagação do fogo. Este trabalho foi realizado no âmbito do projeto PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire" financiado pela FCT, Fundação para a Ciência e Tecnologia.

Palavras chave: Fogos florestais, Simulação, Modelação de incerteza

Simulação de incêndios florestais com base no modelo de Rothermel

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Introdução

A origem e a propagação dos incêndios florestais são cada vez mais estudadas numa tentativa de os prevenir e extinguir com maior rapidez. O combustível, o clima e o declive do terreno são três dos factores que influenciam a forma como o fogo florestal se propaga (1). O modelo de Rothermel (1972) utiliza estes factores para modelar a propagação do fogo. A aplicação do modelo permite calcular a taxa de propagação (R), considerada como a velocidade de propagação do fogo, através da seguinte expressão (2):

$$R = \frac{I_p \xi (1 + \phi_w + \phi_s)}{\rho_w Q_{Lp}}$$

Dentro do factor clima, a velocidade do vento é uma característica determinante para a avaliação da propagação do fogo. A distribuição mais utilizada na literatura para simular a velocidade do vento é a distribuição de Weibull devido à sua flexibilidade, proporcionando um bom ajuste às observações (3). Esta distribuição é caracterizada por dois parâmetros (forma e escala), que podem ser obtidos usando métodos de estimação coerentes (4). O valor destes parâmetros depende das características de cada região (5-8).

Neste trabalho variaram-se os valores dos parâmetros da distribuição de Weibull, por forma a representarem três níveis da escala de Beaufort, que classifica a intensidade do vento segundo níveis de 0 a 12. Foram, assim, aplicados os níveis 2, 6 e 8 representando, respetivamente, uma brisa leve (96 a 198 m/min), um vento forte (648 a 828 m/min) e ventania (1032 a 1242 m/min) (9). Os restantes parâmetros do modelo de Rothermel foram, nesta fase, mantidos constantes.

Metodologia

A floresta é representada por uma rede onde os nodos correspondem a povoadamentos e os arcos à adjacência entre estes povoadamentos (ver figura 1). O peso de cada arco é representado pelo tempo de propagação do fogo que tem em conta a distância entre os dois centros e a velocidade de propagação do fogo (obtida aplicando o modelo de Rothermel).

A variável vento apresenta sempre uma certa incerteza pelo que, na aplicação deste modelo, foi utilizada a distribuição de Weibull para caracterizar a sua velocidade. Neste estudo considerou-se que a velocidade de propagação do fogo é igual em toda a rede. Ao gerar diferentes redes, esta velocidade altera-se tendo em conta o comportamento do vento.

Através do algoritmo de Dijkstra (10), que encontra o caminho mais curto de um nodo de origem para qualquer outro nodo da rede, foram determinadas as distâncias, determinou-se o tempo que o fogo demora a queimar a floresta.

Consideraram-se três níveis diferentes da escala de Beaufort para o comportamento do vento (níveis 2, 6 e 8), e duas alternativas em termos de ignição:

- ponto de ignição variável (aleatório),
- ponto de ignição fixo (nó 0).

Cada um destes cenários foi simulado mil vezes tendo-se determinado, para cada um, a média, o correspondente intervalo de confiança (IC) a 95%, assim como a variância. Por forma a avaliar a existência de diferenças estatisticamente significativas entre as médias do tempo de propagação do fogo a toda a rede, com ponto de ignição variável ou fixo, aplicou-se o teste t para diferença de médias, para cada um dos níveis de vento em estudo. Todas as implementações e análises foram realizadas com recurso à programação em Python.

Resultados e Discussão

Para representar a floresta foi construída uma rede com coordenadas aleatórias de 80 nodos. A figura 1 apresenta a floresta inicial, e a figura 2, a floresta queimada após a aplicação do algoritmo de Dijkstra, assumindo uma brisa leve (na instância ilustrada o tempo observado foi de 28 minutos). Foram, ainda, construídos histogramas para visualizar os resultados, assim como três histogramas que representam o comportamento da velocidade do vento nos três níveis da escala de Beaufort segundo a distribuição de Weibull (ver figuras 3, 4 e 5).

Os resultados obtidos, para os seis cenários, encontram-se na tabela 1.

Analisando os valores de prova dos testes às diferenças de médias dos tempos de propagação do fogo na rede completa, é possível verificar que existem diferenças estatisticamente significativas quando se considera um ponto fixo ou variável, nos níveis 2 e 6 do vento. No nível 8 de vento (ventania) tais diferenças não se revelaram estatisticamente significativas, o que permite inferir que quando o vento é suficientemente forte, o fogo propaga-se rapidamente por toda a rede independentemente do nodo onde inicia.

Trabalho Futuro

- O modelo de Rothermel tem em conta as características e especificidades de cada zona, seria importante considerar todas estas particularidades em cada povoamento.
- Espera-se aplicar estes procedimentos ao caso de estudo, a Zona de Intervenção Florestal do Pinhal e Estre Douro e Sousa e, assim, implementar o modelo de Rothermel em cada povoamento, tendo em conta as suas características.
- Um outro a ser desenvolvido será a utilização da simulação de forma a incorporar outros aspectos importantes na propagação de fogos, nomeadamente:
 - a direção do vento,
 - a existência de projectões,
 - a utilização de recursos para extinguir o incêndio.

	Média	Brisa leve	Vento forte	Ventania
Ponto de ignição variável	38.714	8.887	3.853	
IC a 95%	286.471	47.450	10.930	
IC a 99%	137.664	39.764	18.460	13.648
Ponto de ignição fixo	33.096	7.772	3.549	
Variância	132.483	26.089	6.883	
IC a 95%	132.235	33.957	17.451	8.093
IC a 99%	132.235	33.957	17.451	8.093
Teste t (diferença de médias)	< 0,00005	< 0,00005	0,127	

Tabela 1. Resultados obtidos para os seis cenários relativamente ao tempo de propagação do fogo de cada povoamento.

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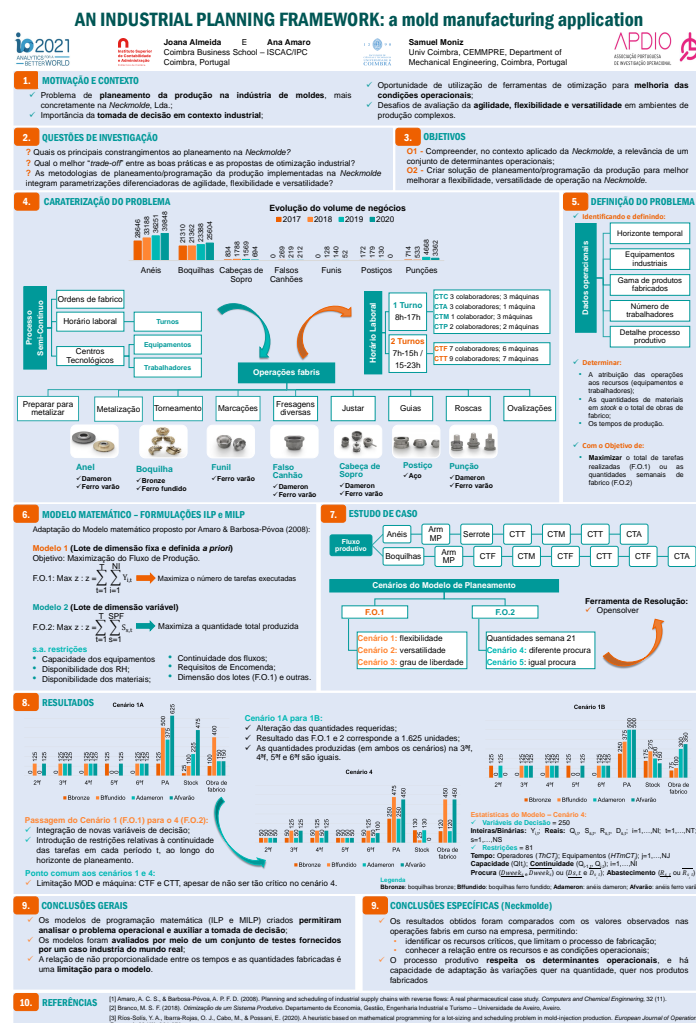
Submissão #61

An Industrial Planning Framework: a mold manufacturing application

Joana Almeida, Ana Amaro, Samuel Moniz

This work is focused on the production planning problem of the mold industry and aims at providing a better understanding of how to achieve operational determinants, such as agility, flexibility, and versatility in complex production environments. The study is concerned with the development of a representation framework for supporting the proposal of integer and mixed-integer linear programming mathematical formulations. The developed models were validated through a set of tests provided by a real-world industrial case. Different planning horizons and operational conditions such as fixed and variable batch dimension, product changeover, minimum and maximum delivery amounts were analyzed. The results obtained were compared with the values observed at the manufacturing operations in progress at the company. These allowed us to identify the critical resources that are limiting the manufacturing process and learn about their relationship with the operational conditions. Also, different model parameterizations proved that a greater amount of production does not mandatory results in a longer production time. Accordingly, the advantage and usefulness of the developed models were demonstrated at the organization on a practical basis.

Keywords: Production Planning, Mathematical Programming, Mold Industry, Flexibility



Submissão #62

A Forest Fire Monitoring System by Wireless Sensor Network

Beatriz Flámia Azevedo, Filipe Alvelos, Ana Rocha, Thadeu Brito, José Lima, Ana Isabel Pereira

Forests worldwide have been devastated by fires. It is known to avoid wildfires catastrophes is fundamental to invest in forest monitorization and systems to detect fire ignitions in the early stages. For this, the development of innovative operations is necessary, such as a forest fire monitoring system based on wireless sensors network. This work concentrates efforts on defining strategic places to allocate a set of sensors inside the forest environment, in order to constitute a forest fire monitoring system. For this, an integer programming model was developed, in which some sensors, with different technical specifications (cost, range distance) are considered and the forest characteristic (forest density and forest fire hazard) is taken into account to define the optimum position for each sensor. The objective is to maximise the coverage provided by the sensors in the area with higher forest fire hazard, considering the sensors and the environmental constraints. The proposed method demonstrated that the methodology can be useful to decision support in the task of spreading sensors into the forest, since it was capable to define optimal points to allocate the sensors in large scale instances. Este trabalho é apoiado pela FCT - Fundação para a Ciência e Tecnologia - no âmbito do projeto da unidade de ID: UIDB/00319/2020.

Keywords: Forest fire, Wireless sensor, Integer Optimization

A Forest Fire Monitoring System by Wireless Sensor Network
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Background

Forests worldwide have been devastated by fires. To avoid wildfires catastrophes is fundamental to invest in forest monitorization and systems to detect fire ignitions in the early stages. Thus, the Forest Alert Monitoring System (SAFe) proposes a monitoring system in the "Serra da Nogueira" located in Bragança - Portugal. This work defines the optimum places to allocate a set of wireless sensors in the forest, in a forest fire monitoring system.

Methodology

An integer programming model was developed considering sensors and forest constraints. An experimental area is defined and the QGIS software is used to map it. The area is divided by a grid the possible location is selected. The objective is to maximize the forest fire hazard covered.

Results

There are 1499 cell available to allocate the sensors, being 7495 the sum of forest fire hazard. 10 sensors were allocated with a maximum budget of 4000 euros. The cost of this layout is 3985 euros, providing a coverage of 1253 cells, which correspond to a forest fire hazard of 6280 units, it is 83.79% of the forest fire hazard.

Mathematical Formulation

Considering the sensor maximum range d_{max} and the forest density interference parameters: f_i^d, f_i^h, f_{max}^d a sensor in the cell c_j can cover the cell c_i , if:

$$\|c_j - c_i\|_2 \leq d_{max} \times \left(1 - \frac{f_i^d + f_i^h}{2f_{max}^d}\right)$$

Location parameters

n = nodes (cell) C_k = cost of sensor k
 h_j = hazard of cell j b = available budget
 l = number sensors that can be allocated

Decision variables

$x_j^k = 1$, if sensor k is allocated in cell j ; else 0
 $y_i^k = 1$, if a cell i is covered by sensor k ; else 0
 $a_{ij}^k = 1$, if sensor k in j covers cell i ; else 0

Objective function:

$$Max z = \sum_{j=1}^n h_j x_j^k$$

Subject to:

$$\sum_{k=1}^l y_i^k \leq 1, \quad i = 1, \dots, l$$

$$\sum_{k=1}^l C_k \sum_{i=1}^n y_i^k \leq b$$

$$\sum_{k=1}^l y_i^k \leq 1, \quad i = 1, \dots, n$$

$$x_j^k \in \{0,1\}, \quad j = 1, \dots, n; \quad k = 1, \dots, l$$

$$\sum_{k=1}^l \sum_{i=1}^n a_{ij}^k y_i^k \geq x_j, \quad j = 1, \dots, n$$

$$y_i^k \in \{0,1\}, \quad i = 1, \dots, n; \quad k = 1, \dots, l$$

Conclusions

Finding an optimal solution to deal with forest fires and is not a simple task, due to the forest complex dynamic. However, the preliminary results demonstrated great potential. As future path it is intend to explore a combination of different forest fire hazard level and study strategies to deal with the sensors overlap value.

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Submissão #63

Modelo de propagação do fogo do tempo mínimo de transmissão em gestão florestal

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Neste trabalho propõe-se a utilização do modelo de propagação de fogo de tempo mínimo de transmissão em gestão florestal. Parte-se da usual representação da paisagem como um conjunto de povoamentos. Para cada povoamento, pretende-se seleccionar uma de entre um conjunto de acções possíveis (i.e. limpeza, corte raso, desbaste, corte de madeira, à?) que definem um plano. Cada plano resulta em diferentes níveis de satisfação de cada um de um conjunto de critérios (e.g. produção de madeira, sequestro de carbono e conservação da biodiversidade). Em vez de modelar a potencial ocorrência de incêndios como um critério (e.g. soma ponderada dos índices de vulnerabilidade dos povoamentos), usam-se cenários (cada um caracterizado por um local de ignição e condições meteorológicas) para excluir planos catastróficos e seleccionar planos aceitáveis. Dado o número de planos ser intratável, usa-se um modulo gerador de planos (com heurísticas construtivas e de pesquisa local) e um módulo avaliador que usa o modelo de propagação do fogo do tempo mínimo de transmissão para avaliar os planos em diferentes cenários. Este trabalho foi realizado no âmbito PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire, financiado pela FCT, Fundação para a Ciência e Tecnologia.

Palavras chave: Propagação do fogo, Heurísticas, Optimização, Gestão florestal



Modelo de propagação do fogo do tempo mínimo de transmissão em gestão florestal

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Contribuições

- Framework para gestão florestal em que a possibilidade de ocorrência de incêndios é modelada explicitamente (em alternativa ao uso de indicadores) através da integração de optimização e simulação.
- Prova de conceito baseada em dados reais considera quatro critérios: valor atual líquido, custo com limpeza de matos, biodiversidade, carbono armazenado e erosão de solo.

Definição do problema

- Dada uma floresta, pretende-se decidir um plano para cada um dos seus povoamentos.
- Plano = prescrição de corte + operações silvícolas adicionais
- Exemplo: cortar eucalipto de 10 em 10 anos com idade inicial de 2 anos e limpar os matos de 3 em 5 anos com início aos 5 anos de idade.
- A cada plano está associado um valor de cada critério em cada ano do horizonte de planeamento obtido com simuladores de crescimento e modelos (ex. equação RUSLE).
- Problema consiste em seleccionar um plano para cada povoamento (plano global)

Modelo Programação Inteira

- Prova de conceito: tratar problema multi-critério associando (P-) restrições a todos menos um objetivo.
- Testes preliminares evidenciam na superavidez da PI em relação a heurísticas construtivas / pesquisa local
- P_i = conjunto ordenado de planos possíveis para o povoamento i
- Parâmetros: $\{p_i, m_i, b_i, c_i, e_i, l_i\}$ - lucros (€), custo (€), índice de biodiversidade (0-7), carbono (ton), erosão (ton) do povoamento i no plano p no ano t.
- Linhas: $\{b_{max}, l_{max}\}$ - b_{max} (ton/ano), l_{max} (ton/ano)
- Variáveis de decisão: $x_{ip} = \begin{cases} 1 & \text{se plano } p \text{ é escolhido para povoamento } i \\ 0 & \text{caso contrário} \end{cases}$

Modelo PI gera plano

Plano global → Proibição planos → MTT simula propagação incêndio

Cada termina quando é encontrado um plano aceitável (verifica existência do PI original e não tem caminhos com velocidade de propagação excessiva)

A vermissão, exemplo de povoamentos com pelo menos um plano que leva a velocidade inaceitável

Simulação da propagação do fogo

- Princípio minimum travel time (MTT) permite determinar os tempos de chegada do incêndio a todos os povoamentos dados os tempos de transmissão entre eles.
- Tempos de transmissão entre povoamentos adjacentes são função da velocidade e orientação do vento, declive e do volume de madeira e mata que dependem dos planos selecionados do ano.
- Para o plano global dado pelo modelo PI, consideram-se todos os anos e todos os critérios com uma ligação (caso não mais curto entre todos os pares de povos da rede que representa a floresta).
- Identificam-se caminhos com velocidade de propagação inaceitável (superior a parâmetro de entrada) e retorna-se informação ao modelo de PI que os exclui.
- Exemplo para caminho de comprimento 2 (povoamentos adjacentes): se a velocidade de propagação entre povoamentos i e j com planos p_i e p_j num período t excede parâmetro v_{max} então, no mínimo, um dos povoamentos pode manter o seu plano: $x_{ip} + x_{jp} \leq 1$.
- Caso não exista nenhum plano global admissível obtém-se, de forma direta, o(s) povoamento(s) onde devem ser implementadas barreiras ao fogo.

Resultados

- Inclinação baseada numa componente das ZIFs de Paiva e Entre Douro e Sousa (300 ha, 38 povoamentos, em média, 12 planos por povoamento)
- Tabela mostra lucros e número de barreiras para diferentes combinações de parâmetros
- Diferentes políticas relativas aos incêndios têm impacto significativo (log-Test, define se são considerados acres os caminhos de comprimento 3)
- Impacto dos parâmetros relativos aos critérios é também significativo

Exemplo dos valores anuais dos critérios

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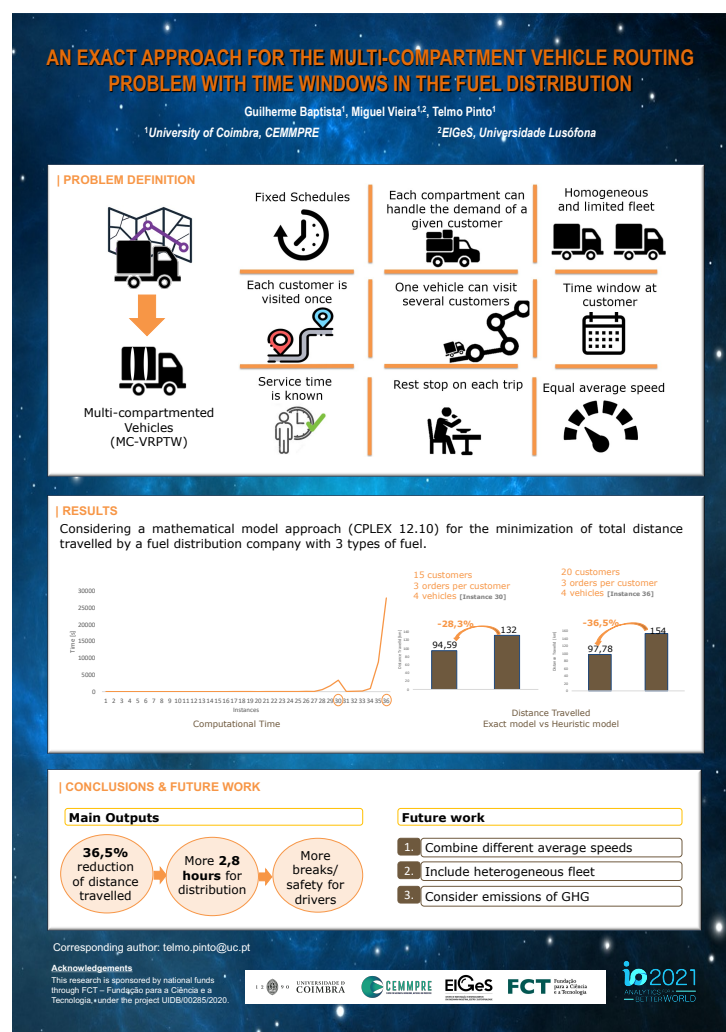
Submissão #64

An Exact Approach for the Multi-Compartment Vehicle Routing Problem with Time Windows in the Fuel Distribution

Guilherme Baptista, Miguel Vieira, Telmo Pinto

Over the years, several authors have widely studied the Capacitated Vehicle Routing Problem, considering different extensions for this problem. An example of these extensions is the Multi-Compartment Vehicle Routing Problem. However, few works from the literature tackle this problem using exact approaches, even more when time windows are explicitly considered. In this sense, we present a mathematical model for the Multi-Compartment Vehicle Routing Problem with Time-windows (MC-VRPTW), taking a fuel retailer company as a case study. Additional constraints that are not commonly addressed in the literature but usually arising from real-world contexts are also considered, such as rest times for the drivers, working time limits, and the maximum duration for each route. Three types of fuels are delivered to a set of customers using a limited homogeneous fleet. Therefore, for each vehicle, it is necessary to determine the route to carry out the deliveries, the instant of time that each customer is visited, the instant time of each break, and the load of each compartment. The efficiency of this exact approach is assessed through a set of computational experiments and by measuring different indicators. Finally, additional tests were performed in real instances from the literature to evaluate the performance of the model.

Keywords: Multi-Compartment Vehicle Routing Problem, Fuel distribution, Mathematical Programming Models




Submissão #66

Personal protective measures for dengue disease: an optimal control approach

Helena Sofia Rodrigues, Artur M. C. Brito da Cruz

Dengue is a vector borne disease, resulting from the duality mosquito-human. Besides the global measures that the health authorities provide to fight this major concern of public health, all individuals could adopt protective measures to reduce the risk of infection. These strategies could be the removal of mosquito breeding sites or the adoption of protective measures to reduce the mosquito bites. The main focus is to study the influence of using personal protective measures (PPM), such as skin repellent, bed nets or clothes treated with mosquito repellent, on the spreading of the disease. An optimal control approach is used to understand the impact in the disease when these measures are added.

Keywords: dengue, personal protection, household costs, optimal control, skin repellent, bed net



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Personal protective measures for dengue disease: an optimal control approach

Dengue is a vector-borne disease considered one of the major concerns in public health. Measures can be used to reduce the impact of the mosquito around the houses. The main focus is mosquito bites prevention through the use of **personal protective measures (PPM), such as skin repellent and bed nets.**

Mathematical model

It is proposed a **system with six ordinary differential equations**, modeling the **interaction human** (s -susceptible, p -protected, i -infected and r -recovered) **and mosquito** (s_m -susceptible and i_m -infected).

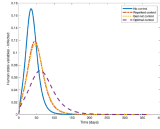
A **functional** is added, related to the household costs with these measures (u_1 - **skin repellent** and u_2 - **bed net**). Through an optimal control analysis, the aim is to understand the best way to apply these measures, diminishing the total dengue cases and the minimization of the cost with the PPM.

$$J(u(\cdot)) = r(T) + \int_0^T (\gamma_1 u_1^2(t) + \gamma_2 u_2^2(t)) dt$$

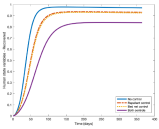
$$\begin{cases} \frac{ds(t)}{dt} = \mu_h - (B\beta_{hm} s_m(t) + u_1(t) + u_2(t) + \mu_h) s(t) + ((1 - \rho_h) + (1 - \rho_e)) p(t) \\ \frac{dp(t)}{dt} = (u_1(t) + u_2(t)) s(t) - ((1 - \rho) + (1 - \rho_e) + \mu_h) p(t) \\ \frac{di(t)}{dt} = B\beta_{hm} s_m(t) s(t) - (\mu_h + \mu_h) i(t) \\ \frac{dr(t)}{dt} = \mu_h i(t) - \mu_h r(t) \end{cases}$$

$$\begin{cases} \frac{ds_m(t)}{dt} = \mu_m - (B\beta_{hm}(t) + \mu_m) s_m(t) \\ \frac{di_m(t)}{dt} = B\beta_{hm}(t) s_m(t) - \mu_m i_m(t) \end{cases}$$

Numerical results

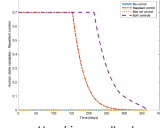


I - infected

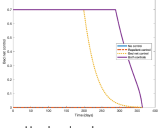


R - recovered

Strategy	Peak of infected persons	Peak's day	Epidemic's end (day)	r(T)	Cost
No control	1912	35	120	10878	0
Only Repellent	863	58	202	9571	42.3
Only Bed net	710	63	223	9083	8.9
Optimal control	510	72	260	8177	71.5
Maximum control	510	72	261	8176	98





U₁ - skin repellent



U₂ - bed net

Conclusions

It is concluded that the application of skin repellent and treated bed nets have an impact on the reduction of infected people and at the same time contributes to the flattening of dengue cases, which could lead to better health cares for each patient.

Submissão #67

A DEA Approach to Evaluate the Electric Mobility Deployment in European Countries

Clara B. Vaz, Ângela P. Ferreira

The European green deal embodies an ambitious plan to fight the climate change, aiming to achieve carbon neutrality, by 2050. Transportation is the remaining sector where emissions are still above the 1990 emissions level, being the road transportation the biggest emitter and the main share of transport energy demand. Main elements of the strategy are the increasing efficiency of the transport system and the use of low-emission energy sources for transport, which can be accomplished by the deployment of the electric mobility. This work aims to assess the performance of European countries on the deployment of low-emission alternative energies and vehicles in road transportation. In order to achieve this aim, a model based on Data Envelopment Analysis (DEA) is used to calculate a composite indicator for several European countries, that aggregates several sub-indicators built from a dataset for the 2019 year. Results obtained indicate that most European countries have potential to improve their practices towards on better road transport sustainability, by emulating the best practices observed on the benchmarks. Additionally, the relative strengths and weaknesses of each country in terms of road sustainability are further explored.

Keywords: DEA, Performance, Electric mobility

A DEA Approach to Evaluate the Electric Mobility Deployment in European Countries

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Introduction

The European green deal embodies an ambitious plan to fight the climate change, aiming to achieve carbon neutrality, by 2050. Transportation is the remaining sector where emissions are still above the 1990 emissions level, being the road transportation the biggest emitter and the main share of transport energy demand.

Main elements of the strategy plan are the **increasing efficiency of the transport system** and the use of **low-emission energy sources** for transport, which can be accomplished by the deployment of the battery electric vehicles and plug-in hybrid electric vehicles (PEV).

This work aims to assess the performance of European countries (27 EU and United Kingdom) on the deployment of low-emission alternative energies and vehicles in road transportation. A Benefit-of-the-doubt (BoD) model based on Data Envelopment Analysis is used to calculate a composite indicator (CI) for several European countries, aggregating several sub-indicators built from a dataset for the 2019 year.

Methodology and Results

Data and Model

Set $M=8$ the selected sub-indicators i , being $m=5$ isotonic and $M-m=3$ reverse, to assess the road sustainability performance of EU countries:

	Household energy length	Railway transport	Public transport market share	PEV market share	Industrial Prod. Index (IPI)	CO2E Emissions Intensity (CO2E/Int)	Energy Intensity (CO2E/Int)	New car registrations
Mean	0.088	0.003	11.707	0.026	1.106	2.101	130.304	122.541
St.dev.	0.003	0.002	4.277	0.004	0.079	1.006	73.450	0.474
Max	0.302	0.121	28.400	0.149	1.316	19.033	206.430	127.660
Min	0.033	0.013	9.400	0.004	0.973	0.935	50.910	16.400

using the BoD model proposed by [1] with proportional virtual weight restrictions [2] for a constant $k \in [0, 1]$ to assess the CI for each country j_0 :

$$CI_{j_0} = \max \sum_{i=1}^m w_i y_{ij_0} - \sum_{v=1}^k w_v y_{vj_0}$$

s.t.

$$\sum_{i=1}^m w_i y_{ij} - \sum_{v=1}^k w_v y_{vj} \leq 1 \quad \forall j = 1, \dots, n$$

$$\frac{1}{M} (1-k) \leq \sum_{i=1}^m w_i y_{ij_0} \leq \frac{1}{M} (1+k) \quad \forall i = 1, \dots, M$$

$$w_i \geq 0 \quad \forall i = 1, \dots, M$$

If no reverse sub-indicators, this model is equivalent to the BoD model [3]

Results

1 Analysis of the CI achieved in 5 scenarios with BoD model for each country using $k=0.5, 0.6, 0.7, 0.8$ and 0.9 (mean)

2 Performance assessment of EU countries in the selected scenario with $k=0.8$

3 Optimal weight structures for each country using $k=0.8$

Conclusions

- CI results are robust for variations of k , except with $k=0.9$, where higher variations were observed. Scenario with $k=0.8$ is adopted as a trade-off between robustness and flexibility.
- 6 benchmarks are identified (AUS, DEN, IRE, LUX, NET, SWE), the mean of CI is 0.66 and St.dev. is 0.27. Most countries have potential to improve road transport sustainability following the best practices adopted mainly by NET and SWE.
- The model allocates more weight to the isotonic sub-indicators (average share=79%) than to the reverse ones (average share=21%) in which the lowest average share is attributed to the electric mobility (4%).
- The performance assessment for each country tends to attribute high proportion to the sub-indicators with higher relative performance and a low proportion to the sub-indicators with poor relative performance, being relevant to identify its strengths and weaknesses.

Main References

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Submissão #68

An Exploratory Analysis of Partition Crossovers for the Travelling Salesman Problem

Rúben Leal, Carlos M. Fonseca

Recombination operators are crucial search operators for the performance of evolutionary algorithms and other meta-heuristics for combinatorial optimisation, whereby new, offspring solutions are generated by combining information from two (or more) parent solutions in some way. The Optimal Recombination Problem (ORP) concerns the generation of the best possible solution that a given recombination operator can produce from given parent solutions. For the Travelling Salesman Problem (TSP), the set of reachable offspring solutions is often restricted to the set of tours containing only edges present in the parents. Optimal tour merging amounts to solving the TSP on the union of the two parent solutions, which is known to be NP-hard even when common edges are preserved [1]. Partition crossovers are deterministic recombination operators that approach the ORP by decomposing parent solutions into components and exchanging them to generate valid, high-quality offspring. One such operator for the TSP is known as Generalised Partition Crossover 2 (GPX2) [2]. Since GPX2 runs in polynomial time, it is necessarily suboptimal. We present an experimental analysis of the performance of this operator in comparison to optimal tour merging, with and without enforcing preservation of common edges, and to other more restricted forms of the ORP, with a view to identifying opportunities for further improving GPX2. References: [1] Anton Eremeev and Julia Kovalenko. "Optimal Recombination in Genetic Algorithms for Combinatorial Optimization Problems: Part II". In: Yugoslav Journal of Operations Research 24.2 (2014), pp. 165-186. doi: 10.2298/YJOR131030041E; [2] Renato Tinós, Darrell Whitley, and Gabriela Ochoa. "A New Generalized Partition Crossover for the Traveling Salesman Problem: Tunneling between Local Optima". In: Evolutionary Computation 28.2 (June 1, 2020), pp. 255-288. doi: 10.1162/evo0a00254.

Keywords: Optimal Recombination, Partition Crossover, Travelling Salesman Problem



Partition Crossovers for the TSP: An Exploratory Analysis

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1. Introduction

Recombination operators combine information from two (or more) solutions in order to generate a new solution.

The **Optimal Recombination Problem (ORP)** [1] concerns the generation of the best possible solution that a given operator can produce from given parent solutions.

For the Travelling Salesman Problem (TSP), **Optimal Tour Merging (OTM)** solves the ORP by solving the TSP on the union of two parent tours. This problem is NP-hard even when common edges are preserved [1].

Generalized Partition Crossover 2 (GPX2) [3] is a **partition crossover** that operates as follows:

- The union of two tours is decomposed into so-called candidate components.
- A candidate component is a recombining component if the corresponding original sub-tours can be selected interchangeably to produce a new tour.

- Non-recombining candidate components are successively fused with one another until the result is recognised as a recombining component or no further fusion is possible.

- At the end, components that were not recognised as recombining components are merged into one last (recombining) component.

- For each recombining component, the best of the two corresponding sub-tours is selected in order to produce the new tour.

An experimental analysis of the performance of GPX2 in relation to two forms of OTM is presented in this work. With a view to identifying opportunities for further improvement, this analysis also includes an idealised partition crossover partly based on GPX2.

2. Experimental Setup

Locally optimal tours were generated for three TSP instances of sizes 52, 150, and 200, by running Iterated Local Search (ILS) with 2-opt neighbourhood and double-bridge perturbation.

Up to 1000 pairs of tours were selected for recombination by uniform sampling according to the number of different edges between parents (bond distance).

Three operators were used besides GPX2:

- Optimal Edge Preserving Recombination (OEPR) is the standard OTM implemented using ILP [2].
- Optimal Respectful Edge Preserving Recombination (OREPR) is OTM subject to the preservation of common edges, also implemented using ILP.
- Exhaustive Generalised Partition Crossover (GPX_{ex}) performs an exhaustive search for the best combination of sub-tours of all GPX2 candidate components instead of performing fusions.

3. Results and Discussion



Figure 1. Instance berlin52.

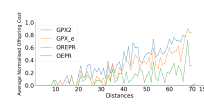


Figure 2. Instance ch150.

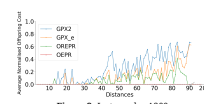


Figure 3. Instance kroA200.

- Results normalised based on optimal tour length and the length of the best parent tour.
- Preserving common edges in OTM reduces the quality of the resulting tours somewhat.
- Candidate component identification in GPX2 further reduces the quality of the achievable tours (GPX_{ex}).
- The remaining reduction in tour quality in GPX2 can be attributed to the fusion stage.

4. Edge Selections for Each Operator



Figure 4. Union of two tours.

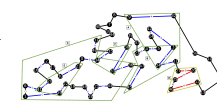


Figure 5. GPX2 tour.

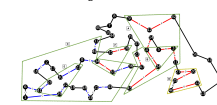
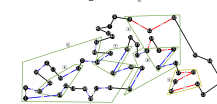
Figure 6. GPX_{2-E} tour.

Figure 7. OREPR tour.

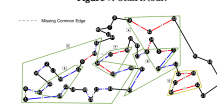


Figure 8. OEPR tour.

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Submissão #69

A simulation-based methodology for uncertainty analysis in life cycle assessment

Andreia Santos, Ana Carvalho, Ana Barbosa-Póvoa

According to the European Commission, life cycle assessment (LCA) is the best methodological tool for assessing the potential environmental impacts associated with a product's life cycle. To determine the potential environmental impacts, different parameters are required which are calculated using data from several sources with different levels of reliability. The uncertainty associated with the data used causes the parameters utilized in an LCA to be uncertain and consequently, causes uncertainty in the outcome of an LCA study. To increase the confidence of the decision-makers in LCA results and on the decisions taken under these results, parameter uncertainty should be taken into account when conducting a life cycle assessment. This study presents a new methodology for integrating parameter uncertainty in an LCA study. This methodology involves conducting a traditionally deterministic LCA analysis that does not consider uncertainty, a stochastic LCA analysis, which considers the uncertainty associated with the different parameters, and a comparison of both analyses. The stochastic modelling technique applied in this study is Monte Carlo simulation. To illustrate how the developed methodology can be applied, this work presents the application of the developed methodology to the life cycle of Portuguese natural cork stoppers.

Keywords: Life cycle assessment, Uncertainty analysis, Monte Carlo simulation, Natural cork stoppers, Sustainable supply chain management



A simulation-based methodology for uncertainty analysis in life cycle assessment

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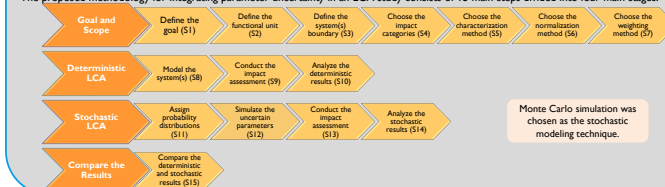
*Corresponding author: andreia.d.santos@tecnico.ulisboa.pt

Introduction

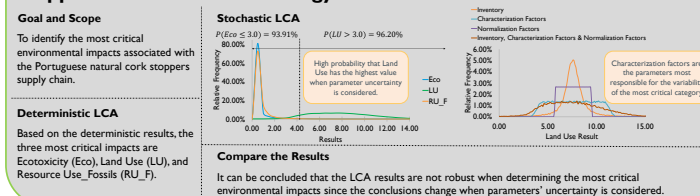
- Life cycle assessment (LCA) uses several parameters to determine the potential environmental impacts associated with a product's life cycle;
- These parameters are uncertain due to the large amount of data needed to calculate them;
- Parameter uncertainty causes uncertainty in the outcome of an LCA study which affects decision-making;
- To increase the confidence of the decision-makers in LCA results and on the decisions taken under these results, parameter uncertainty should be considered when conducting a life cycle assessment.

Methodology

The proposed methodology for integrating parameter uncertainty in an LCA study consists of 15 main steps divided into four main stages:



Application of the Methodology



Conclusions

This study presents a new methodology for integrating parameter uncertainty in an LCA study. The proposed methodology was applied to a case study and based on the results obtained, it can be concluded that Land Use is the most critical environmental impact associated with the Portuguese natural cork stoppers supply chain which was not the conclusion reached when parameter uncertainty was not considered. This conclusion reinforces the importance of the proposed methodology since it highlights how uncertain the outcome of an LCA study can be.



Acknowledgements

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Submissão #70

Gestão da cadeia de abastecimento das vacinas: o projeto e planeamento da distribuição


Inês Duarte, Bruna Mota, Ana Barbosa-Póvoa

O planeamento e gestão das cadeias de abastecimento farmacêuticas é um processo complexo e enfrenta inúmeros desafios dadas as características únicas e exigentes da deste setor da indústria (Lemmens et al., 2016). Tornar estas cadeias de abastecimento mais sustentáveis, não só considerando objetivos económicos e ambientais, como também preocupações sociais é crucial. Em particular, incluir aspetos de equidade é de extrema relevância, no sentido de tornar estes produtos disponíveis e acessíveis a nível global (Menou, Hornstein and Lipton-McCombie, 2021). A ferramenta de apoio à decisão apresentada segue o trabalho desenvolvido por (Mota et al., 2018), onde um modelo multi-objetivo é proposto de forma a integrar decisões a nível estratégico e tático, considerando os três pilares de sustentabilidade. Este modelo foi aplicado a um caso de estudo real cujos resultados permitem avaliar diferentes cenários de otimização, bem como estudar a influência dos objetivos económicos, ambientais e sociais nas diferentes atividades presentes na cadeia de abastecimento. Desta forma, este trabalho propõe uma ferramenta que permite o projeto e planeamento das cadeias de abastecimento farmacêuticas, onde a integração de aspetos sociais constitui o grande foco e contributo.


Palavras chave: Cadeias de abastecimento farmacêuticas, Sustentabilidade, Equidade, Projeto e Planeamento



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“Pharmaceutical industry supply chains: planning vaccines’ distribution”


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Objectives

Development of an optimization model for the design and planning of a sustainable supply chain in the pharmaceutical industry sector, where the integration of social concerns is the main contribution.

Model Development

Based on ToBLuOM (Triple Bottom Line Optimization Modeling), proposed in Mota et al. (2018).



Qualitative Indicators from Access to Medicine Index

Availability and Affordability in countries with the highest disease burden and lowest ability to pay Registration/coverage programmes
Donation programmes
Equitable pricing strategies

Quantitative Indicators

$$\max \text{PharmAccess} = \left(\sum_i e^{\text{DALY}_i} \cdot Y_i \right)$$

Early related parameter: Social factor of demand based on DALY metric
Decision Variable: 1 or 0 entries is installed
Priority: the location of entries in countries with higher disease burden

$$\max \text{PharmDistr} = \min \left(\frac{\text{Supply}}{\text{Demand}} \right)$$

Integer Variable: Amount of product allocated to a country where entry is installed, in time period t
Demand: Demand of product on by client in time period t
Priority: Determine the optimal number of accesses to be distributed to a country. Maximize the minimum delivery-to-demand ratio in each country, thus enforcing access equity among countries.

- Social Constraint -

$$\left(1 - \frac{\text{PharmDistr}}{\text{DALY}_{\text{max}}} \right) \leq \delta_{\text{poor}}$$
In terms of economic and financial crisis, the aim is often to optimize costs while respecting sustainable (non-optimal) levels of efficacy, rather than maximizing profits.
 ✓ Ensuring a minimum level of access for those with lower ability to pay for pharmaceuticals.
 ✓ Avoiding thresholds of lack of provision due to poverty.

Contributions


- Development of a **multi-objective** MILP model to support supply chain design and planning decisions, based on a Triple Bottom Line Optimization Modeling tool (Mota et al., 2018);
- Sustainability indicators addressed as objective functions in the developed model, while considering particularities associated with pharmaceutical products;
- Integration of social objectives, including availability and affordability concerns, thus achieving a more socially equitable solution;

Preliminary Results

- Pharmaceutical SCs are complex and face a context of increasing uncertainty;
- Modelling social SC indicators is challenging;
- Social concerns lead to different supply chain networks;
- It is possible to obtain sustainable pharmaceutical SC, where a trade-off can be achieved comprising the three goals: economic, environmental and social objectives;

Case-study

Meningococcal Meningitis Vaccines' Supply Chain
(Pharmaceutical company Sanofi Pasteur)

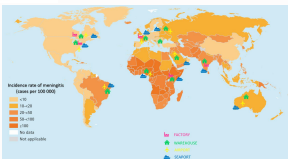


Decisions

- Network structure;
- Supply flow amounts;
- Entities' capacities;
- Transportation network;
- Technologies' selection and allocation;
- Levels of production and refrigeration.

Supply Chain Superstructure

Geographical areas as the main markets of meningitis vaccines:
U.S., Europe, Latin America, Eurasia, Asia, Africa & Middle East, and Rest of the world





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Submissão #71

An optimization approach to aggregate production planning with combined MTS-MTO production strategy

José Vila-Chã, Diogo Pereira da Silva, Daniel Pereira, Eduardo Ribeiro, Manuel Pina Marques

Production strategy definition and appropriate medium-term production planning are two crucial aspects to the success of industrial companies. A study was conducted in a company operating in the wine industry with two main objectives: finding the best production strategy for each product considering a hybrid make-to-stock/make-to-order production system and developing an optimization approach to aggregate production planning. The proposed approach for production strategy definition considers the impact that a change in the production strategy of one product has in the whole system by modeling congestion effects using M/G/1 queues. The process consists of a greedy heuristic that changes the production strategy of the product that, at each iteration, provides the highest savings. Once a strategy change occurs, costs and congestion effects of the whole system are recalculated, and the process is repeated until no more savings can be achieved. Regarding the aggregate production planning problem, an optimization model based on mixed-integer programming formulation was developed. With the goal of minimizing a global cost function, the model determines the most efficient and leveled allocation of production resources that meets the fluctuating demand. By applying the developed methodologies, the company is expected to achieve significant savings.

Keywords: Aggregate production planning, Make-to-order, Make-to-stock

An optimization approach to aggregate production planning with combined MTS-MTO production strategy

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²Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, s/n, 4600-001, Porto, Portugal

Introduction

The work carried out in this project aimed to improve two correlated aspects of the planning process of a **Portuguese company operating in the wine sector**: production strategy definition and aggregate production planning. The objective was to develop a methodology to be implemented in a decision support system capable of assisting the company's planning department to choose the best production strategy for each product and to plan capacity and allocate resources in the medium term.

Context and Motivation

- Production strategy is highly **dependant** on a commercial definition.
- Current procedures have **reduced analytical support**.
- Master production plans are **not systematically generated**.
- Production planning requires a **holistic approach** that accurately represents the company's **complex production context** and **absorbs the seasonality effects**.



The work was divided into two separate modules

1 Defining the optimal production strategy for each product of the company

2 Generating medium-term aggregated production plans

Goal: Finding the optimal trade-off between operational and inventory costs

1. Production Strategy Definition – MTS/MTO

- To find the best production strategy for each product, a **hybrid make-to-stock/make-to-order** production system was considered. The process consists of a **greedy heuristic** that changes the production strategy of the product that, at each iteration, provides the highest savings. Once a strategy change occurs, costs and congestion effects of the whole system are recalculated, and the process is repeated until no more savings can be achieved.
- The proposed approach for production strategy definition considers the impact that a change in the production strategy of one product has in the whole system by modeling **congestion effects** using **M/G/1 queues**.

Heuristic:

- All products are initiated as MTS
- Beginning of a new iteration
- For each product, calculate the costs of producing it as MTS and as MTO
- Reorder and change the strategy of the product with the highest savings
- Repeat until no more savings are possible
- A set of Business rules are applied to guarantee the service level in the MTOs

Product	Strategy	Cost MTS	Cost MTO	Savings
A	MTS	€	€	€
B	MTO	€€€	€€	€€
C	MTO	€€	€	€

2. Aggregate production planning – Optimization model

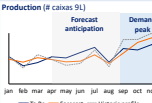
- An **optimization model** based on **mixed-integer programming** formulation was developed to address the aggregate production planning problem. With the goal of **minimizing a global cost function**, the model determines the most efficient and leveled allocation of production resources that meets the fluctuating demand.

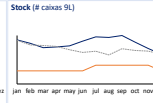
Objective Function €
 Minimize a global cost function composed of the following costs:
 Inventory (Storage & holding)
 Labour
 Setup
 Production line operation

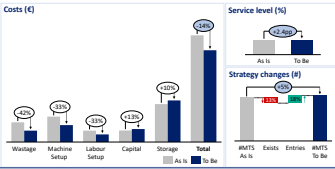
Model constraints
 The model is subjected to constraints associated with:
 Sales forecast
 Production strategy
 Inventory
 Resource allocation
 Ecology

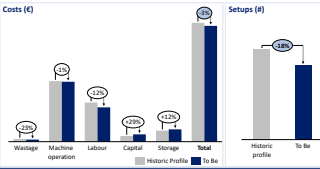
Results

Problem data and MIP features		MIP Dimensions		Solution time	
Product	1	Variables	1542	Branch nodes	124
Product	196	Constraints	4379	Branch and bound	124
Product	196	Iterations	1542	Branch and bound	124
Product	196	Iterations	1542	Branch and bound	124









1. Conclusions

- The developed **heuristic** for the production strategy definition leads to a **significant cost reduction**.
- The incorporation of **congestion effects** allows for an **integrated view** of the impact that the change in production strategy of one product has on the others.
- The aggregate planning model generates **optimised production plans** that minimise the company's total costs and **level out the allocation of production resources**.
- The use of the developed tools will enable a **much faster planning process**.

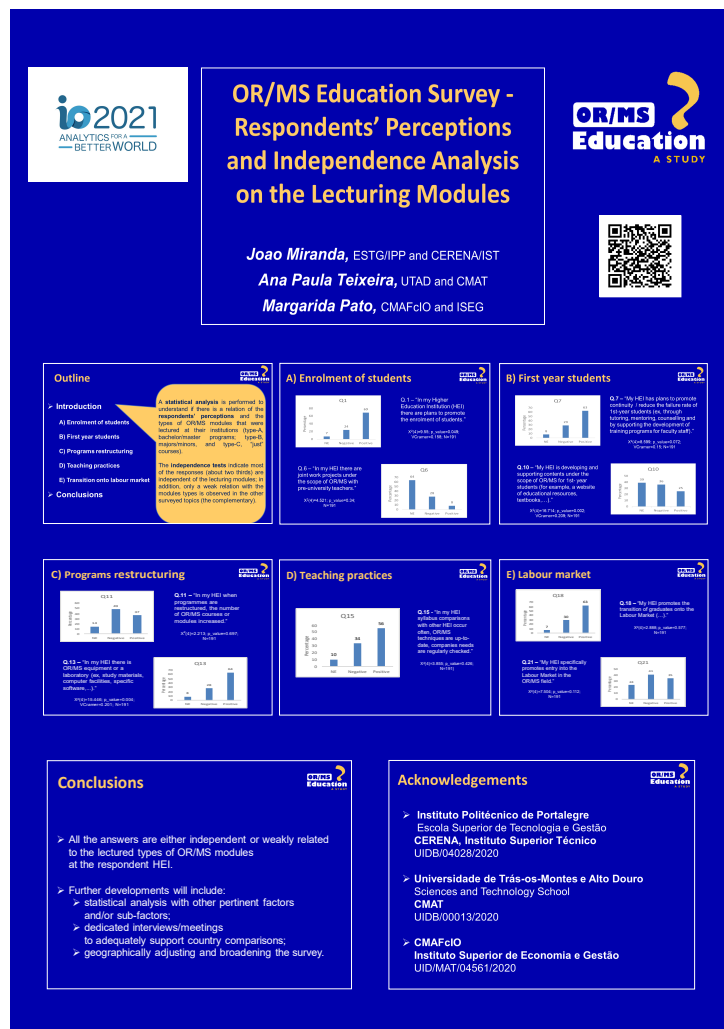
Submissão #72

OR/MS Education Survey - Respondents' Perceptions and Independence Analysis on the Lecturing Modules

Joao Luis de Miranda, Ana Paula Teixeira, Margarida Vaz Pato

This work addresses the respondents' perceptions in a survey conducted with the aim of learning from important developments in the European Higher Education area concerning the Operational Research/Management Science (OR/MS) field. The study regards, in particular: (i) the enrolment; (ii) the reduction in 1st year students' failure rates; (iii) the perceived value of OR/MS courses; (iv) the OR/MS teaching practices; and (v) the transition onto the labor market. A statistical analysis is performed to understand if there is a relation of the respondents' perceptions and the types of OR/MS modules that were lectured at their institutions (type-A, bachelor/master programs; type-B, separate majors/minors, and type-C, courses). The independence tests indicate most of the responses (about two thirds) are independent of the lecturing modules; in addition, only a weak relation with the modules types is observed in the other surveyed topics (the complementary). In this way, the respondents' perceptions are revisited, and further developments are discussed while addressing OR/MS Education within this evidence-based approach.

Keywords: OR/MS education, Enrolment, Retention, Restructuration, Teaching, Transition into labor market, Statistical analysis



Submissão #73

Last-mile Delivery with Crowdsourcing

Tiago Monteiro, João Pedro Pedroso, Ana Viana

E-commerce has suffered a substantial increase in the last years. Customers buy more often online and expect quicker deliveries with smaller shipping fees. That represents a challenge for retailers that need to ensure service quality and efficiency over the multiple phases of the supply chain. We will study new models and algorithms to optimize the last phase of delivery of online purchases: last-mile delivery. In particular, we will exploit the concept of crowdsourcing in which, in addition to professionals, ordinary citizens (a.k.a. occasional couriers - OCs) participate in the delivery process. This problem combines two well-known problems in the literature: routing and matching. Parcels are matched with occasional couriers, and routes are generated for the company fleet and occasional couriers. For such a study, we develop a simulator that enables companies to understand how crowdsourcing can benefit them. Mainly, we aim to consider the stochasticity of potential occasional couriers when making decisions in terms of availability and the expected compensation. We further extend this work by incorporating machine learning/reinforcement learning tools into the simulator to evaluate diverse matching and compensation strategies and estimate their outcome.

Keywords: Last-mile Delivery, Crowdsourcing, Simulation, Machine Learning

Last-mile Delivery with Crowdsourcing

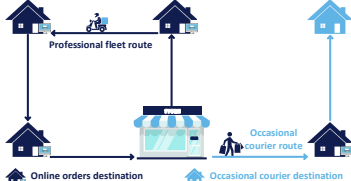
Tiago Monteiro, João Pedro Pedroso, Ana Viana

Crowdsourcing: ordinary people enroll in a program to deliver goods to the final customer on their way home with no or little detours for a compensation (occasional couriers, OCs)

Routing and Assignment Problem:

- × **Online orders:** "final consumer" of last-mile delivery
- × **Workforce:** deliveries can be done either by occasional couriers or by the store own fleet (professional fleet)

Objective: determine deliveries for occasional couriers and routes for professionals that lead to minimum distribution cost given by the professional fleet delivery costs plus the compensation given to occasional couriers



Approach: design a simulator that allows businesses to study and understand if this delivery model is suitable for them and under which assumptions (configurations)

Challenges:

- × **Dynamism:** the decisions must be taken online (the OCs/online orders arrive at the store during the day)
 - × Multiple Scenario Approach
- × **Stochasticity:** the occasional couriers can accept or reject the delivery tasks proposed to them (e.g., depending on the extra journey they are willing to execute and the compensation they get)
 - × Scenario Planning, Reinforcement Learning
- × **Scenario Generation:** online orders/OCs demand generated by Generative Adversarial Networks
- × **Optimization:** Mixed Integer Programming (MIP), Assignment rules/heuristics

Configuration

Online orders

Workforce

Occasional Couriers

Professional fleet


Stochastic

Yes No

Assignment Strategy

Routing Strategy

Simulation



Simulation Statistics





Routes

● Store
● Online order
● Occasional courier

Average Cost

...

Acknowledgements: This work is partially funded by the ERDF – European Regional Development Fund through the Operational Program for Competitiveness and Internationalization - COMPETE 2020 Program, and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia, within project POCI-01-0145-FEDER-028611 and through the individual research grant 2020.06686.BD.




Submissão #74

ϵ -constraint algorithms for the Pareto front representation of multi-objective integer programming

Mariana Mesquita-Cunha, José Rui Figueira, Ana Barbosa-Póvoa

Many decision problems, although sometimes modeled as single objective, are, in fact, multi-objective problems. However, showing a full Pareto front to a decision maker may be overwhelming. Hence, one option is to select a subset of the Pareto front to present to the decision maker. Nevertheless, that raises the questions of which solutions to present to the decision maker and, furthermore, how can we focus on generating only the desired subset of Pareto front solutions. Considering that a good subset of solution is one where the uniformity, coverage and cardinality of the subset are considered, three generation algorithms based on the ϵ -constraint method that address each of those concerns are put forward. Additionally, the algorithm that targets the subset's cardinality and the one that focuses on uniformity present procedures that skip the search for redundant solutions. Finally, all three algorithms are insensitive to the quality of the estimation of the Pareto front extremes. Results show that the proposed algorithms, apart from generating representations of the Pareto front, are also competitive when generating the full Pareto front.

Keywords: Multi-objective generation method, ϵ -constraint, Integer programming, Generation method

ϵ -constraint algorithms for the Pareto front representation of multi-objective integer programming

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Introduction

Many decision problems, although modeled as single objective, are, in fact, multi-objective problems. However, showing a full Pareto front to a decision maker (DM) may be overwhelming. Hence, one option is to select a subset of the Pareto front (PF) to present to the DM.

That raises the questions of:

- Which solutions to present to the DM?
- How to generate only the desired subset of PF solutions to present to the DM?

Representation problem

- Coverage:** How does the representation cover all regions of the objective space included in the PF, $N(Z)$

$$\min \Gamma(R(N), N(Z)) = \max_{z \in N(Z)} \min_{z' \in R(N)} d(z, z')$$
- Uniformity:** How diverse and equally spaced are the points in the representation, i.e., how spread

$$\max \Delta(R(N)) = \min_{z, z' \in R(N), z \neq z'} d(z, z')$$
- Cardinality:** The number of outcome vectors considered

$$\min \Pi(R(N))$$

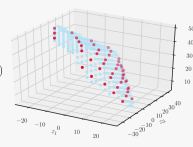


Figure 1 - Example of a Pareto front for a three objective problem where in blue are all the Pareto front points and in red the ones computed using a representation algorithm

Methodology

Three ϵ -constraint algorithms targeting each dimension of the representation problem

- Early exit strategy on all loops
- Redundancy elimination that enables the use of poor nadir point estimations

$$\max z_k(x) + \beta \sum_{k=1, k \neq q} (10^{k-1} \times s_k / r_k)$$

s.t. $x \in X$
 $z_k(x) - s_k = \epsilon_k \quad \forall k = 1, 2, \dots, p, k \neq q$

```

graph TD
    Start([Start]) --> ComputeNadir[Compute ideal and the nadir point for each objective (z_k^id and z_k^nad, k = 1, 2, ..., p)]
    ComputeNadir --> SelectObj[Select objective function q and algorithm]
    SelectObj --> InitLoop[Initial loop control variables: epsilon_k = z_k^id - z_k^nad, z_k^id = z_k^nad, k = 1, 2, ..., p, k != q]
    InitLoop --> Decision1{epsilon_2 <= z_2^id}
    Decision1 -- NO --> End([End])
    Decision1 -- YES --> Decision2{epsilon_{p-1} <= z_{p-1}^id}
    Decision2 -- NO --> AdjustParam2[Adjust parameter epsilon_{p-2}]
    AdjustParam2 --> Decision1
    Decision2 -- YES --> Decision3{epsilon_q <= z_q^id}
    Decision3 -- NO --> AdjustParam3[Adjust parameter epsilon_{p-1}]
    AdjustParam3 --> Decision2
    Decision3 -- YES --> CheckRedundancy[Check computation redundancy and obtain solution]
    CheckRedundancy --> Feasible{Feasible?}
    Feasible -- NO --> Decision1
    Feasible -- YES --> RecordSol[Record solution x_k, x_{k-1}, ..., x_{p-1}, x]
    RecordSol --> UpdateWorst[Update worst values z_k^id = min(z_k^id, z_k), k = 1, 2, ..., p - 1, k != q]
    UpdateWorst --> AdjustParam4[Adjust parameter epsilon_q]
    AdjustParam4 --> Decision1
    Feasible --> Coverage{Is coverage algorithm?}
    Coverage -- YES --> EarlyExit[Early exit from loop]
    Coverage -- NO --> Decision1
    
```

Results

Table 1 - Algorithms' results when computing the whole Pareto front, as number of iterations per non-dominated Pareto front solution. Results are shown as mean values for 30 instances.

	AUCM-2 ^{PI}	SAUGM ^{PS}	Cov.	Uni.	Card.
MO 0.1 - knapsack instances					
3x50x1	78.76	1.89	14.37	1.89	1.89
3x75x1	52.09	1.82	11.69	1.83	1.83
3x100x1	42.89	1.79	9.28	1.79	1.79
MO Multi-dimensional 0.1 - knapsack instances					
3x25x4	1.92	1.92	1.92	1.92	1.92
MO integer knapsack instances					
3x50x1	1.98	1.71	1.71	1.71	1.71
MO Multi-dimensional 0.1 - knapsack instances					
3x25x2	1.93	1.89	1.89	1.89	1.89
3x25x3	1.91	1.88	1.88	1.88	1.88
3x25x4	1.93	1.92	1.92	1.92	1.92

Table 2 - Algorithms' results for the Pareto front representation problem. Results are shown as mean values for 30 instances.

	ϵ_k	Algorithm	[I]	[F]	[Δ]
3x50 5	Cov.	25.83	186.67	29.43	
		Uni.	13.60	274.33	46.53
		Card.	15.33	205.00	42.93
17	Cov.	113.70	113.53	8.20	
		Uni.	67.40	168.90	14.40
		Card.	112.20	114.53	8.30
25	Cov.	153.53	98.77	6.70	
		Uni.	102.17	143.63	10.03
		Card.	168.83	94.13	5.87

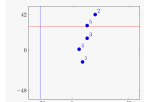


Figure 2 - Example of the coverage algorithm search procedure

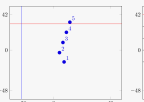


Figure 3 - Example of the uniformity algorithm search procedure

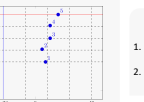




Figure 4 - Example of the cardinality algorithm search procedure

Conclusions

- Uniformity and cardinality algorithms proved to be amongst the most efficient algorithms in literature
- Cardinality algorithm shows higher flexibility, privileging, more uniformity or coverage, depending on cardinality.

[1]Mavrotas, G., Florios, K., 2013. Applied Mathematics and Computation 219, 9652-9669

[2]Zhang, W., Reimann, M., 2014. European Journal of Operational Research 234, 15-24

Acknowledgements

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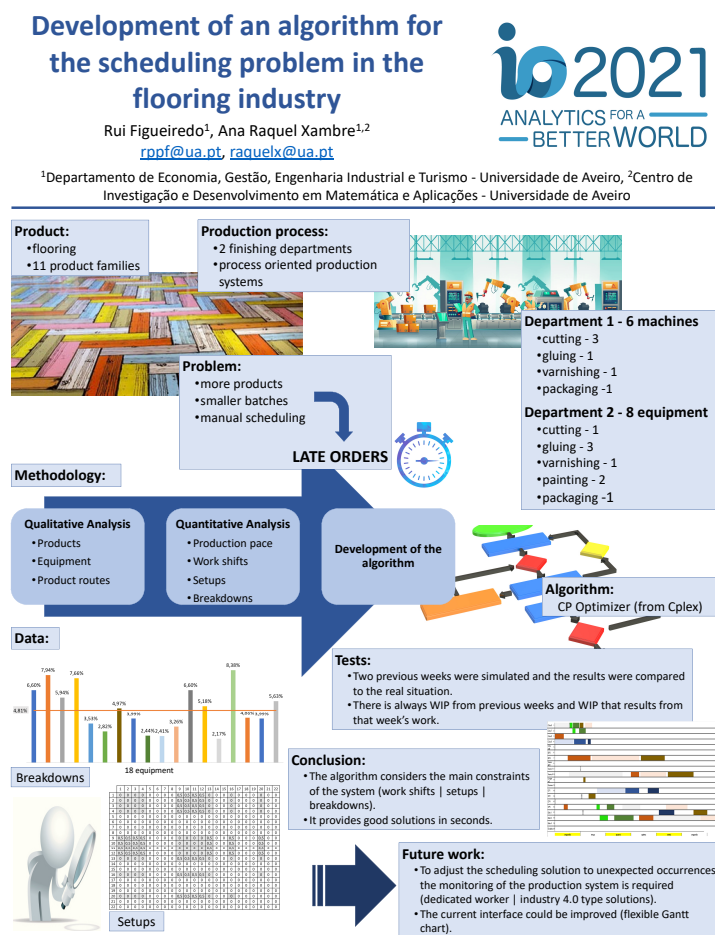
Submissão #75

Development of an algorithm for the scheduling problem in the flooring industry

Rui Figueiredo, Ana Raquel Xambre

This work was developed in a flooring industry that is currently facing an increase of product variety and a decrease of batch sizes. This high mix-low volume environment has led to a higher complexity of the production system and made intuitive scheduling more difficult. As such, a scheduling algorithm adapted to the needs of the company was developed in order to obtain, in a more formal and logical way, a solution to the scheduling problem. First, an analysis of the production system was carried out which helped to identify the factors that should be considered, namely: products, routes, production pace, setup times, work shifts and breakdowns. On a second stage, the structure of the procedure was designed taking into account that it should integrate the aforementioned factors. In the validation stage, two weeks of production were chosen and the scheduling was simulated. The objective of the work was achieved, the algorithm was developed and is operational for the reality of the company. Even so, given the complexity of a scheduling system for this type of environment, improvements were identified, namely making the algorithm more flexible to user inputs, and improving the interaction platform.

Keywords: Scheduling, High mix-low volume, Algorithm



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Submissão #76

Preventing food loss and waste in the fruit and vegetable supply chain: a multi-criteria approach

Vanessa Magalhães, Luis Ferreira, Cristóvão Silva

Reducing food loss and waste (FLW) is a global concern, but little research has been performed to develop tools to guide the selection of suitable mitigation strategies and to evaluate the strategies' effectiveness to achieve the targeted goals. Therefore, this study develops and presents a three-phase evaluation framework to identify, evaluate and rank potential mitigation strategies to fight FLW. The framework was tested in the context of the Portuguese fruit and vegetable supply chain (FVSC). In the first phase, a literature review is performed and focus group discussions (FGD) are used to identify potential strategies to tackle the causes of FLW experienced in the FVSC. The second phase uses the fuzzy Step-wise Weight Assessment Ratio Analysis (SWARA) method to determine the relative weights of the evaluation criteria for FLW mitigation strategies. Finally, in the third phase, the fuzzy weighted aggregated sum product assessment (WASPAS) is used to rank the mitigation strategies. Results show that preventing FLW is a shared responsibility, highlighting the role of collaboration, coordination and information sharing towards the prevention and reduction of FLW. Overall, this paper provides researchers, practitioners and policymakers with a structured approach to prioritise cost effective efforts with higher environmental and social gains.

Keywords: Food Loss and Waste, Fruit and Vegetable Supply Chain, Mitigation Strategies, Fuzzy Step Wise Weight Assessment Ratio Analysis, Fuzzy Weighted Aggregated Sum Product Assessment



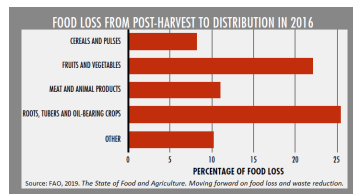
Preventing food loss and waste in the fruit and vegetable supply chain: a multi-criteria approach

Vanessa S. M. Magalhães¹, Luís Miguel D. F. Ferreira¹, Cristóvão Silva¹

¹Univ Coimbra, CEMPRE, Department of Mechanical Engineering, Coimbra, Portugal

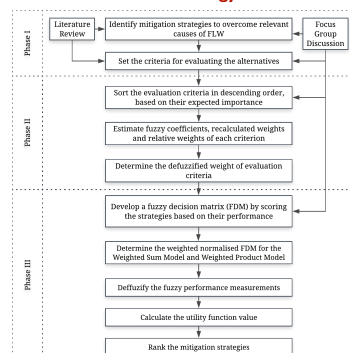
Introduction

- The Target 12.3 of the United Nation's 2030 Agenda for Sustainable Development calls for the halving of per capita global food waste at the retail and consumer levels and the reduction of food losses along production and supply chains, including post-harvest losses, by 2030.



- There is a lack of literature dedicated to the development of tools to guide the selection of suitable mitigation strategies and to evaluate the strategies' effectiveness to achieve the targeted goals.

Methodology



Results

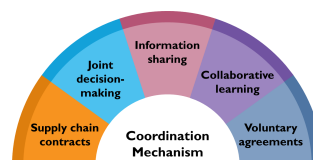
Ranking of the Mitigation Strategies for FLW in the FVSC:

- Share and maintain information regarding the remaining shelf-life
- Training staff on handling practices
- Ensure communication among FSC stages
- Implement automated demand forecasting systems
- Develop and use intelligent packaging to monitor quality
- Improve visibility along the FSC through traceability systems
- Correct date marking to avoid confusion
- Find new markets for overproduction
- Invest in more and regularly maintain storage facilities
- Develop new packaging to enhance shelf-life
- Implement integrated IT systems through the FSC
- Improve cooling methods
- Ensure adherence to standard procedures
- Improve transport infrastructures
- Improve the means of transportation
- Adjust packaging size



Conclusions

- Information-related strategies have higher performance towards FLW reduction.
- Preventing FLW is a shared responsibility, with collaboration, coordination and information sharing playing a major role in FLW reduction.
- Sharing information can minimise the mismatch between supply and demand and improve the quality of decisions that relate to the product's shelf life.



Acknowledgements:

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Submissão #77

Towards an Application Programming Interface for Constructive Search

Samuel Outeiro, Carlos M. Fonseca

Optimisation practice is intimately related to the availability of software tools to support it. Current approaches to combinatorial optimisation typically fall into one of two broad classes: glass-box mathematical programming formulations and solvers, such as integer linear programming (ILP) and constraint programming (CP), and black/grey-box problem models and (usually heuristic) algorithms implemented directly in software. The latter may be more flexible and easier to integrate into existing workflows, but the lack of a de-facto standard for modelling/implementing optimisation problems in software hinders its adoption in practice. In fact, different optimisation software frameworks usually require problems to be implemented in that framework. In addition, most such frameworks strongly emphasise local search algorithms over constructive search. The development of an Application Programming Interface (API) for constructive search problems and algorithms is the main focus of this work. The problem formulation is separated from the algorithm that solves it by specifying a number of abstract elementary operations that problems must implement and solvers can use in a problem-independent way. Both exact and (meta-)heuristic algorithms are supported, including Branch and Bound, Beam Search, GRASP and Ant Colony Optimisation algorithms, among others. A discussion of the implications of the proposed abstraction for the development of novel constructive search algorithms concludes the presentation.

Keywords: Constructive Search, Combinatorial Optimisation, Software



Towards an API for Constructive Search

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Motivation

- There is no de-facto standard for modelling and implementing optimisation problems as constructive-search problems.
- This is in contrast to Integer Linear Programming (ILP) and Constraint Programming (CP).
- Opportunity for the development of an Application Programming Interface (API) for constructive-search problems and algorithms.

API Development

- Solutions can be seen as subsets of components from a larger set – the ground set.
- Solutions may be feasible or infeasible, and partial or complete.
- When constructing a solution, components may be present, absent or forbidden.
- Construction obeys certain rules.

Proposed API

- Data structures:
 - Problem, solution, component.
- Elementary operations on solutions:
 - Add or remove components.
 - Forbid or permit components.
 - Generate empty or heuristic solutions.
 - Compute bounds on (partial) solutions.
 - Evaluate feasible solutions.

Example

```

Construction Step in GRASP
Sample heuristic: Move(WOR(ADD)) while list is not full
Add component to list
Select a component at random from list
Add component to solution with applyMove(ADD)
Branching in Branch & Bound
Sample heuristic: Move(ADD) to obtain component c
Add c to solution with applyMove(ADD)
Expand solution further (recursion)
Remove c from solution with applyMove(REMOVE)
Forbid c in solution with applyMove(FORBID)
Expand solution further (recursion)
Permit c in solution with applyMove(PERMIT)
Return (end recursion)
  
```

References

[1] Vukobratović, B., Stokich, R. L., Bekasov, B. D., Bekasov, K. L., and Stokich, R. L. The Cable Trench Problem: Combining the Shortest Path and Maximum Spanning Tree Problems. *Computers & Operations Research* 28, 5 (2001), 445–454.

**Validation**

- Demonstrate the expressiveness of the API by implementing a set of problems models:
 - TSP, QAP, MKP, CTP
- and a set of solvers:
 - B&B, IG, GRASP, ACO, Beam Search

Experimental Analysis**Evaluation of API Overhead**

- B&B based on the API vs. handcrafted B&B implementation.
- Applied to random instances of the Cable Trench Problem (CTP) [1].
- Slowdown lower than three times (and may be further reduced).

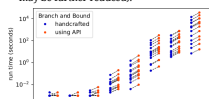


Figure 1. Run times of two B&B implementations

Solver Performance Evaluation

- Metaheuristics: ACS, ANTS, AS, MMAS, GRASP (construction phase only).
- Applied to TSP instances from TSPLIB.
- Very weak lower bound: the length of the partial tour.
- 1000 × (no. cities) constructions per run.

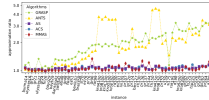


Figure 2. Solver performance

- Applied Friedman test with a significance level of 0.05 – null hypotheses was rejected.
- Applied Nemenyi post hoc test with a significance level of 0.05.
- Ranking: MMAS ACS AS ANTS GRASP.

Effect of the Model on Solver Performance

- Applied MMAS and ANTS to TSP instances.
- Three different lower bounds:
 - The length of the partial tour (Weak).
 - The length of the partial tour + the lengths of the shortest $n - k$ arcs not included in the tour (Intermediate)
 - The length of the partial tour + the length of the MST for the graph consisting of not visited cities + the lengths of the two shortest connecting arcs (Strong)
- 1000 × (no. cities) constructions per run.
- Implementation of the Strong bound was not optimised. Some instances did not run to completion in the allotted time (48h).

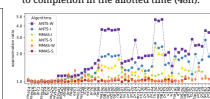


Figure 3. Effect of bounds on solver performance

- Applied Friedman test and Nemenyi post hoc test as before.
- Ranking: MMAS-S MMAS-W ANTS-S MMAS-I ANTS-I ANTS-W.
- The Strong bound does appear to improve the quality of the results, but the difference is only significant for ANTS.

Concluding Remarks

- Solvers can be transparently applied to problem models and vice-versa.
- Problem implementation effort can be made incrementally.
- Improved models potentially benefit all solvers.
- Small set of implemented solvers so far.
- Simplest lower-bound semantics in the multi-objective case.
- Dynamic programming not supported, yet.
- Lack of user familiarity with the API (unlike with ILP or CP).


Submissão #78

The impact of uncertainty on planning and scheduling of human-robot assembly lines

Miguel Vieira, Samuel Moniz, Bruno S. Gonçalves, Tânia Pinto-Varela, Ana Barbosa-Póvoa, Pedro Neto

The complexity of production environments due to uncertain demand and processing variability have been recognised as a common problem in the development of efficient planning and scheduling tools. In this work, we explore an optimisation-simulation method based on the Recursive Optimisation-Simulation Approach (ROSA) to provide decision-support for integrated production planning and scheduling, combining a mathematical optimisation module with a high-resolution discrete-event simulation model. The advantage of this iterative approach is that the simulation can incorporate the system dynamics and stochastic behaviour, reducing the optimisation problem hindrance by leaving some of the hard-to-model constraints for the later. Through an industrial case study of a multistage assembly line collaboratively operated by humans and mobile shared robots, the work focusses on the advantages of the hybrid approach in the definition of planning and scheduling solutions, given a process layout with available workstation resources to produce a set of products with a defined sequence of operations steps. We highlight the overall impact of the uncertainty parameters integration in the methodology in order to guarantee capacity-feasible solutions, given the assessment of the operational process dynamics.

Keywords: production planning and scheduling, optimisation-simulation method, uncertainty



#78

The impact of uncertainty on planning and scheduling of human-robot assembly lines

Miguel Vieira^{a,b,c}, Samuel Moniz^a, Bruno S. Gonçalves^d, Tânia Pinto-Varela^b, Ana Paula Barbosa-Póvoa^b and Pedro Neto^a

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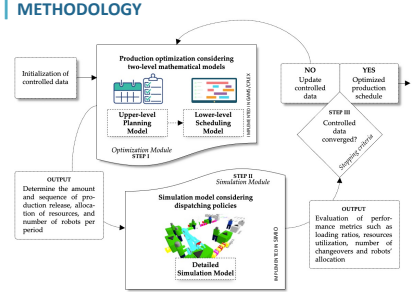
SCOPE

- Development of efficient planning and scheduling tools due to uncertain demand and processing variability

MOTIVATION


- Problem complexity of industrial production environments
- Hybrid optimisation-simulation method based on the Recursive Optimisation-Simulation Approach (ROSA)
- Aggregated MILP optimisation module with a high-resolution discrete-event simulation model → incorporates the system dynamics and stochastic behaviour of the industrial process

METHODOLOGY



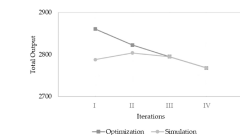
The methodology is an iterative process. It starts with 'Initialization of controlled data' leading to 'Production optimization considering two-level mathematical models'. This involves an 'Upper-level Planning Model' and a 'Lower-level Scheduling Model' within an 'Optimization Module (STEP I)'. A decision diamond asks 'Controlled data converged?'. If 'NO', it loops back to 'Production optimization'. If 'YES', it proceeds to 'STEP II Simulation Module' which uses a 'Simulation model considering dispatching policies' and a 'Detailed Simulation Model'. An 'OUTPUT' box evaluates performance metrics like loading rates, resource utilization, and changeovers. A final decision diamond asks 'Simulation converged?'. If 'NO', it loops back to 'Production optimization'. If 'YES', it leads to 'SOLUTION'.

CASE STUDY



- Industrial multistage assembly line collaboratively operated by humans and mobile shared robots → multiproduct workstations layout and sequence of operations steps
- Uncertainty parameters → human tasks' processing times, robots velocity, sequence-dependent setup times, robot battery repair, and random micro-stoppages
- Assessing different scenarios (e.g. type/number, processing times, demand), process layout configurations (e.g. resources performance, setup downtimes and bottlenecks) → evaluate cost-effective planning/scheduling solutions feasibility to minimize costs and makespan


RESULTS HIGHLIGHTS



The graph shows 'Total Output' on the y-axis (ranging from 2700 to 2900) and 'Iterations' on the x-axis (I, II, III, IV). Two lines are plotted: 'Optimization' (solid line with circles) and 'Simulation' (dashed line with squares). Both lines show an upward trend, with the Optimization line consistently higher than the Simulation line. The Optimization line reaches approximately 2850 at iteration IV, while the Simulation line reaches approximately 2800.

- Iterative procedure relevant to overcome computational challenges with such decisional levels
- Robust assessment to capacity-feasible planning, given the operational process dynamics → e.g. task allocation of a set of collaborative mobile robots
- Uncertainty impact on solution convergence with ROSA requires to further explore alternative mathematical optimisation approaches

Vieira, M., Moniz, S., Gonçalves, B. S., Pinto-Varela, T., Barbosa-Póvoa, A. P., & Neto, P. (2021). A two-level optimisation-simulation method for production planning and scheduling: the industrial case of a human-robot collaborative assembly line. *IO 2021*.



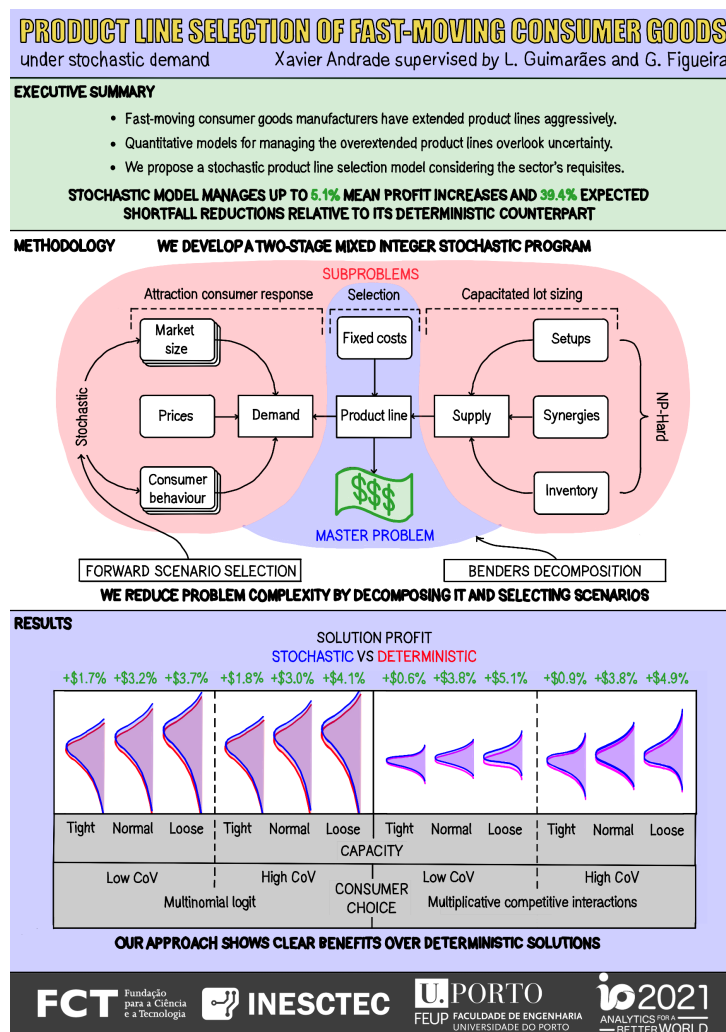
Submissão #79

Product line selection of fast-moving consumer goods under stochastic demand

Xavier Andrade, Luis Guimarães, Gonçalo Figueira

Selecting fast-moving consumer goods product lines requires deep insight into projected production costs and demand volumes, given the sector's thin margins. Demand volumes are difficult to estimate, because both the total market size and each individual product utility are subject to considerable uncertainty. This paper tackles product line selection for fast-moving consumer goods producers, incorporating market sizes and product utility uncertainty. We propose a stochastic formulation to determine profit-optimizing product lines. Sequentially, our approach makes a selection and, when demand reveals itself, computes complexity costs by solving a capacitated lot-sizing problem. We address this model's complexity on two fronts: using Bender's decomposition and reducing the number of scenarios to consider. The decomposition method drastically cuts solution times, particularly for instances with small subproblems. The scenario reduction procedure achieves equivalent stability to random draws using almost one-third of the scenarios. Lastly, we analyze the value of the stochastic solutions under different random utility models, attractiveness coefficients of variation, and capacity conditions. The stochastic approach leads to clear benefits in expected profit, managing up to 5.1% mean profit increases and 39.4% expected shortfall reductions compared to deterministic solutions.

Keywords: Product line selection, Stochastic programming, Multinomial logit, Multiplicative competitive interaction, Lot sizing



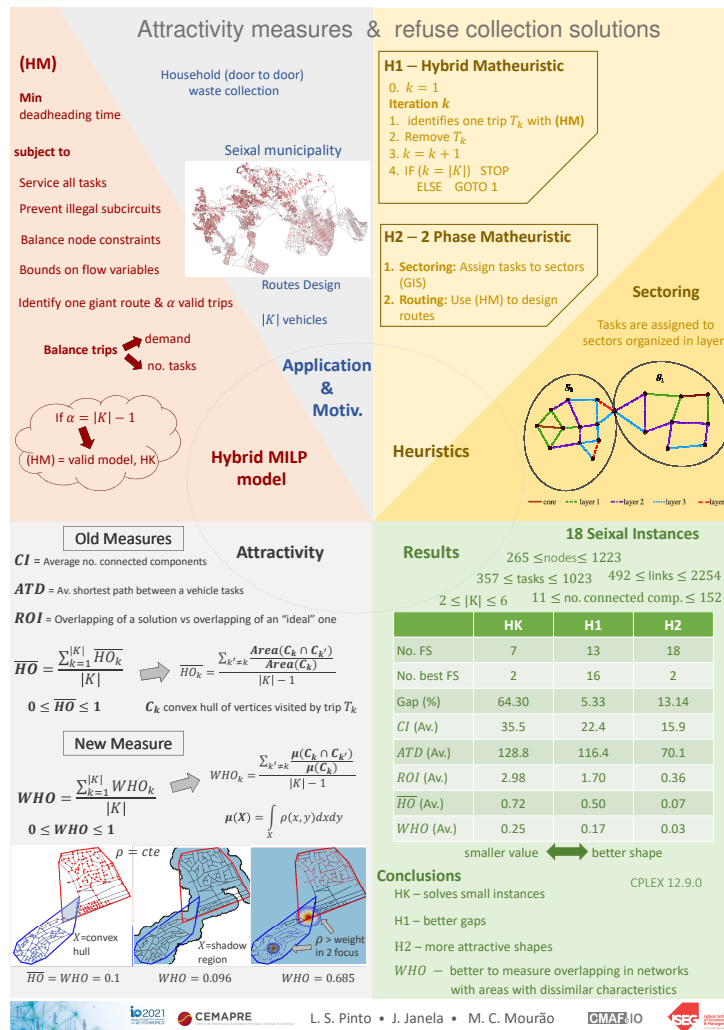
Submissão #80

Attractive measures refuse collection solutions

Leonor Santiago Pinto, João Janela, Maria Cândida Mourão

Refuse collection solutions are usually validated through the total time. We propose an attractive measure that aim to evaluate the solutions' fitness to address a real case study. Solutions are gathered by hybrid matheuristics compared with the ones obtained by a mixed integer linear programming model for a mixed capacitated arc routing problem. This study was motivated by a household waste collection system in the Portuguese municipality of Seixal. The GIS tool, available at the municipality, is used not only for the input/output but as an alternative method to design sectors as it provides spatial information. The methods developed and the model are tested on real based instances and the results of that computational experience reported and analyzed including attractiveness measures.

Keywords: Attractiveness measures, Mixed capacitated arc routing, Matheuristics, GIS



Submissão #81

Das florestas às redes na modelação da propagação do fogo

Susete Marques, Mariana Dias, Isabel Martins, Filipe Alvelos

Os principais modelos de propagação do fogo à escala da floresta baseiam-se na representação da paisagem como uma rede em que os nodos correspondem a células e os arcos a relações de adjacência. Naturalmente, diferentes definições das células e das relações de adjacências conduzem a diferentes redes, quer em termos de estrutura, quer em termos de dimensão. Neste trabalho, propõem-se abordagens de definição de redes tendo em conta a relação entre a granularidade das células, definições de adjacência e influência nos modelos de propagação de fogo, utilizando o software Flammap. Este trabalho foi realizado no âmbito PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire" financiado pela FCT, Fundação para a Ciência e Tecnologia.

Palavras chave: Modelos de propagação do fogo, Redes, Flammap

DAS FLORESTAS ÀS REDES NA MODELAÇÃO DA PROPAGAÇÃO DE INCÊNDIOS

Susete Marques (1,2), Mariana Dias (1), Isabel Martins (2,3), Filipe Alvelos (4,5)

PROBLEMA
Como é que o tempo de propagação de um incêndio numa floresta, simulado pelo Flammap, é influenciado pela definição de adjacência entre os povoamentos?

CASO DE ESTUDO – ZIFs Paiva e Entre Douro e Sousa

Povoamentos	Número	Área (ha)
Em corte raso	251	2244,4
Eucalipto com Pinheiro	64	615,6
Eucalipto com Sobreiro	4	69,8
Pinheiro com Eucalipto	38	416,2
Pinheiro com Sobreiro	1	2,3
Castanheiro	1	5,5
Eucalipto	920	9990,5
Pinheiro	85	751,4
Bipolares	41	111,6
Sobreiro	1	12,8
	1406	14230,1

FLAMMAP
O FlamMap simula a propagação de um incêndio numa paisagem. O tempo de propagação do incêndio é calculado com base em modelos de comportamento do fogo e no algoritmo *minimum travel time* (Finney 2002) aplicado a um grafo que representa a paisagem.

GRAFOS DA FLORESTA COM DIFERENTES DEFINIÇÕES DE ADJACÊNCIA
Duas unidades de gestão (vértices do grafo) são adjacentes (arestas do grafo) se

1. Partilharem um ponto pelo menos
2. Partilharem uma fronteira com f metros ou menos
3. Estiverem a uma distância inferior ou igual a d metros.

TRABALHO EM CURSO
(1) T. Francês, P. Pinto

(1) Centro de Estudos Florestais e Laboratório TERRA, Universidade de Lisboa; (2) Instituto Superior de Agronomia, Universidade de Lisboa; (3) Centro de Investigação Aplicações Fundamentais e Investigação Operacional, Universidade de Lisboa; (4) Algarves, Universidade do Minho; (5) Departamento de Produção e Sistemas, Universidade do Minho

Logos: D3F, INSTITUTO SUPERIOR DE AGRONOMIA, Universidade do Alentejo, FCT

Submissão #82

Integração dos modelos de Rothermel e do tempo mínimo de transmissão para modelação da propagação do fogo


João Pedro Silva, João Marques, Rita Amaral, Senhorinha Teixeira, José Carlos Teixeira, Susete Marques, Mariana Dias, Isabel Martins, Catarina Santos, Ana Raquel Xambre, Helena Alvelos, André Mendes, Filipe Alvelos

Incêndios florestais são classificados como fenómenos complexos, com dimensões de tempo e espaço que variam numa escala de segundos e milímetros a mais de um dia e mais de um quilómetro. Quando ocorre em florestas, o fogo pode ter um enorme impacto nos seres humanos, pois coloca a vida e propriedades em perigo. Portugal foi o único país dos Estados Membro da União Europeia com um decréscimo da área florestal nas últimas três décadas. Os incêndios florestais são a razão por detrás desta redução, o que faz com que a gestão do combustível florestal, e da floresta em geral, seja fundamental para evitar danos no ecossistema. Neste sentido, prever este fenómeno é de grande importância para a tomada de decisões na prevenção e combate. Deste modo, propõe-se a integração do modelo de Rothermel no modelo do tempo mínimo de transmissão. Este último representa a paisagem como uma rede, com tempos de transmissão do fogo associados aos arcos, e determina o tempo de chegada do fogo a qualquer ponto da rede de forma eficiente através de um algoritmo de caminhos mais curtos (e.g. algoritmo de Dijkstra). Neste trabalho exploram-se modelos de propagação do fogo em que os tempos de transmissão nos arcos da rede do tempo mínimo de propagação são obtidos com o modelo de Rothermel. Este trabalho foi realizado no âmbito PCIF/GRF/0141/2019 "O3F - An Optimization Framework to reduce Forest Fire" financiado pela FCT, Fundação para a Ciência e Tecnologia.

Palavras chave: Incêndio Florestal, Modelação Matemática, Rothermel

Integração dos Modelos de Rothermel e do Tempo Mínimo de Transmissão para Modelação da Propagação do Fogo

João Pedro Silva (1,2), João Marques (3), Rita Amaral (2), Senhorinha Teixeira (2,4), José Carlos Teixeira (1,3), Susete Marques (5,6), Mariana Dias (6), Isabel Martins (6,7), Catarina Santos (8,10), Ana Raquel Xambre (9,10), Helena Alvelos (9,10), André Mendes (11), Filipe Alvelos (2,4)



ANALYTICS FOR A BETTER WORLD

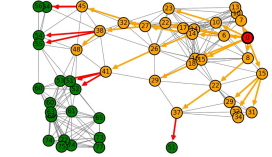
Objetivos

- **RotherMTT: Modelo integrado para simular a propagação do fogo para:**
 - Avaliar propagação do fogo à escala da paisagem;
 - Integração da propagação de fogo na otimização da utilização de recursos na extinção de incêndios;
 - Integrar otimização e simulação da propagação de incêndios em gestão florestal.

Metodologia

- **Modelo de Rothermel**
 - Estima a taxa de propagação com base nas propriedades do combustível, declive e vento.
 - Condições constantes - adequado para um povoamento, mas não para floresta (heterogénea).
 - Equação principal:
$$R = \frac{I_R \xi (1 + \Phi_W + \Phi_S)}{\rho_b \epsilon Q_{ig}}$$
- **RotherMTT: Integração Rothermel + MTT**
 - Todos os potenciais tempos de transmissão do fogo entre povoamentos adjacentes são calculados com o modelo de Rothermel;
 - Tempos de chegada do fogo a todos os povoamentos são calculados seguindo o princípio MTT

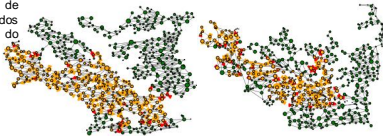
- **Minimum travel time (MTT)**
 - Princípio *Minimum travel time*: o incêndio segue o caminho por onde se propaga mais rapidamente.
 - Floresta representada por uma rede em que nodos são povoamentos / unidades de gestão (homogéneos) e arcos representam adjacências.
 - Conhecidos os tempos de propagação entre povoamentos e dada uma ignição, um algoritmo de árvore dos caminhos mais curtos (e.g. Dijkstra) permite determinar o tempo de chegada do fogo a cada célula.
 - Exemplo: valores nos nodos correspondem a tempos de chegada dada a ignição no nodo vermelho, cores retratam o estado do incêndio no instante 50).



Resultados

Caso de Estudo: Zonas de Intervenção Florestal de Paiva e Entre Douro e Sousa

- Área total: 14320 ha (1406 povoamentos).
- Aplicação do modelo RotherMTT: conversão de dados da floresta (altura e biomassa dos centros dos povoamentos, vento dominante) em parâmetros do modelo de Rothermel.
- Estado do incêndio nos dois componentes após 10 minutos para local de ignição dado.



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Submissão #83

A Holistic Framework for Increasing Agility in a Production Process




Leonor Magalhaes, João Guedes, Jorge Freire

Following the globalization and technological development, markets become progressively more volatile and dynamic, perceiving new competitive advantages related to agility. The urge to produce faster and at a lower cost, without compromising customer needs, is emerging in a new era where adaptability is the key. Thus, this study focuses on the development of an agility framework. A project within a leader metal packaging industry worked as the framework trigger. Agility increase was the main target, where production line flexibility leverage and equipment efficiency optimization were also contemplated. However, different barriers to agility were unveiled. To solve the agility problem, four concepts seem to have an impact in that direction, such as Equipment Efficiency, Product Complexity, Portfolio Management and Production Planning. This paper is centered in how these four forces interact to influence an agile manufacturing and in understand the methodologies to overcome the problem. The different concepts mentioned above are implemented, as a rule, separately with a clear line of action. However, in the context of the project, the integration of the four overlapped concepts was crucial, prompting the development of an agility framework that will be presented in this study.

Keywords: Agility, Overall Equipment Efficiency, Production Planning, Product complexity

A Holistic Framework For Increasing Agility in a Production Process

L.G. Magalhães, J.Guedes and J.F. Sousa

SUMMARY

Following globalization and technological development, markets become progressively more volatile, perceiving new competitive advantages related to agility. The urge to produce faster and at a lower cost without compromising customer needs is emerging in a new era where adaptability is the key. Four concepts seem to impact that direction in order to solve the agility problem: Equipment Efficiency, Product Complexity, Portfolio Management, and Production Planning. This study is centered on how these four forces interact to influence agile manufacturing and understand the methodologies to overcome the problem. The different concepts mentioned above are implemented, as a rule, separately with a clear line of action. However, the integration of the four overlapped concepts was crucial, prompting the development of an agility framework.

METHODOLOGY

The framework trigger was a project within a leader metal packaging company where agility increase was the primary target. The practical experience combined with the literature review based on the areas identified as agility influencers allowed the framework development. The literature review focused on the interactions between the four concepts that affect flexibility within a production process.

RELATIONSHIPS REVIEW

Table 1 represents the generic characteristics that fit into the agility problem, integrating also the relationships between them.

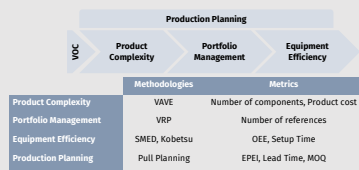
	Portfolio Management	Product Complexity	Equipment Efficiency	Production Planning
Portfolio Management	A great number of references	-	-	-
Product Complexity	Redundancy of products	A great number of components with no value-added	-	-
Equipment Efficiency	A great number of setups	Product features that bring complexity to production process	-High setup time -Low OEE	-
Production Planning	-High levels of stock -Complexity in production sequence	An early point of differentiation in the value chain	High EPEI	-Long lead times -High MOQ

Table 1 - Generic matrix of characteristics that fit into the agility problem

OEE- Overall Equipment Efficiency
EPEI- Every Part Every Interval
MOQ- Minimum Order Quantity

AGILITY FRAMEWORK


The proposed framework systematizes both the sequence and the methodologies for leveraging the agility of a production process.




	Methodologies	Metrics
Product Complexity	VAVE	Number of components, Product cost
Portfolio Management	VRP	Number of references
Equipment Efficiency	SMED, Kobetsu	OEE, Setup Time
Production Planning	Pull Planning	EPEI, Lead Time, MOQ

Voice of the customer (VOC) is an input of the framework since it is fundamental to understand customer's requirements with respect to the product that is offered.

Value Analysis Value Engineer (VAVE) corresponds to the methodology used to reduce product complexity.




VALUE ANALYSIS
Evaluating existing Product Specifications




VALUE ENGINEERING
Implementing Disruptive Innovations

→ Maximizing product value


Variety Reduction Program (VRP) corresponds to the methodology used to optimize portfolio management.



Single Minute Exchange of Die (SMED) and Kobetsu correspond to the methodologies used to leverage equipment efficiency.

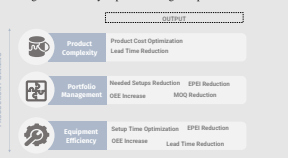


SMED
Method focused on reducing unproductive changeover time



KOBETSU KAIZEN
Machine-focused method, applied to the lower efficiency machines

Production Planning is continuously improved through the previous framework steps.



Submissão #84

Seller-buyer supply chain: A game theory framework

João P. Almeida, Carla A. S. Geraldès, João P. Coelho

We present a game theoretical framework to study competition and collaboration scenarios in seller-buyer supply chains, representing a manufacturer that wholesales a product to a retailer who, in turn, retails to the final consumer. We study cooperative and non-cooperative scenarios, by considering in the first case a Stackelberg game under both the situations where one of the players, either the buyer or the seller, plays the leading role by taking the initiative and forcing the strategy of the other player, the follower. In the cooperative game, we analyse scenarios where the profit of both players are increased when applying joint cooperative strategies. We also compute the Nash equilibria. This is undergoing work.

Keywords: Seller-buyer supply chain, Game theory, Stackelberg game, Nash equilibrium



Seller-buyer supply chain: A game theory framework

João P. Almeida, Carla A. S. Geraldès, João P. Coelho

CeDRI – Polytechnic Institute of Bragança

Introduction and background

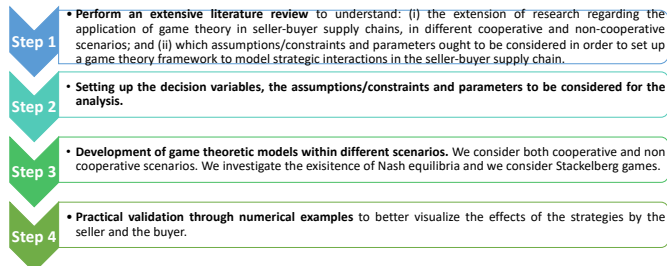
We consider a seller-buyer supply chain consisting of a manufacturer which wholesales a product to a retailer who, in turn, retails it to the final consumer. The interaction between seller and buyer can be analysed by considering cooperative and non-cooperative scenarios, as well as leader-follower scenarios. This sets the perfect environment to introduce Game Theory as a tool to model the strategic interactions between the two players in the named different scenarios.

Objectives

To develop a game theory framework to model the strategic interaction of one seller and one buyer in a seller-buyer supply chain.

To consider different scenarios (cooperative and non-cooperative) and study which strategies are Nash equilibria regarding the profit of both players

Methodology & goals



Contributions

- An extensive literature review has been performed.
- Decision variables considered: Price charged to the buyer by the seller, Lot size and price practiced by the buyer to the final consumer.
- Different scenarios were considered: cooperative and non-cooperative.
- Stackelberg games were considered in the non-cooperative scenario.

Acknowledgement

This work has been supported by FCT - Fundação para a Ciência e a Tecnologia within the Projects Scope UIDB/05757/2020.

Submissão #86

Designing and testing the IMPACT HTA socio-technical framework to assist HTA agencies in the multicriteria evaluation of new medicines on a common basis

Mónica Oliveira, Teresa Rodrigues, Liliana Freitas, Ana Vieira, Klára Dimitrovová, João Bana e Costa, Aris Angelis, Panos Kanavos, Carlos Bana e Costa


When evaluating medicines, Health Technology Assessment (HTA) committees consider multiple value dimensions, variable quantity and quality of evidence, as well as make use of their qualitative knowledge regarding medicines' impacts; and at the top level, HTA agencies face the challenges of promoting consistency in medicines evaluations across committees and of finding a balance in the involvement of HTA stakeholders and experts in evaluations. In this study we describe the development and testing of the IMPACT HTA socio-technical framework to assist HTA agencies in valuing medicines in multiple dimensions across diseases on a common basis. Technically, the framework combines MACBETH with concepts of the swing weighting matrix so that a common value frame is set by the HTA agency for groups of therapeutic indications, and committees evaluate medicines on a structured basis and departing from the value set defined by the agency. Socially, the framework is developed through a collaborative modelling approach in which key HTA stakeholders and members of evaluation committees are involved in a sequence of Delphi and decision conferencing processes so as to develop both the value frame for each therapeutic indication, and MACBETH value models for specific medicines' evaluations. Results from testing the HTA framework in case studies developed in two HTA agencies from Belgium and Sweden are presented, and feedback and insights from participants about the framework are provided.

Keywords: Multicriteria Decision Analysis, Health Technology Assessment, Socio-Technical Approaches, MACBETH, Collaborative Value Modelling

DESIGNING AND TESTING THE IMPACT HTA SOCIO-TECHNICAL FRAMEWORK TO ASSIST HEALTH TECHNOLOGY ASSESSMENT AGENCIES IN THE MULTICRITERIA EVALUATION OF NEW MEDICINES ON A COMMON BASIS

Mónica Oliveira¹, Teresa C. Rodrigues², Liliana Freitas¹, Ana Vieira¹, Klára Dimitrovová¹, João Bana e Costa², Aris Angelis^{3,4}, Panos Kanavos⁴, Carlos Bana e Costa¹

¹ CES-IST, Instituto Superior Técnico, Universidade de Lisboa; ² Decisionsays; ³ London School of Hygiene and Tropical Medicine; ⁴ Department of Health Policy and LSE Health, London School of Economic




Abstract: When evaluating medicines, Health Technology Assessment (HTA) committees consider multiple value dimensions, variable quantity and quality of evidence, as well as make use of their qualitative knowledge regarding medicines' impacts; and at the top level, HTA agencies face the challenges of promoting consistency in medicines evaluations across committees and of finding a balance in the involvement of HTA stakeholders and experts in evaluations. In this study we describe the development and testing of the IMPACT HTA socio-technical framework to assist HTA agencies in valuing medicines in multiple dimensions across diseases on a common basis. Technically, the framework combines MACBETH with concepts of the swing weighting matrix so that a common value frame is set by the HTA agency for groups of therapeutic indications, and committees evaluate medicines on a structured basis and departing from the value set defined by the agency. Socially, the framework is developed through a collaborative modelling approach in which key HTA stakeholders and members of evaluation committees are involved in a sequence of Delphi and decision conferencing processes so as to develop both the value frame for each therapeutic indication, and MACBETH value models for specific medicines' evaluations. Results from testing the HTA framework in case studies developed in two HTA agencies from Belgium and Sweden are presented, and feedback and insights from participants about the framework are provided.

Context: Challenges in HTA agencies

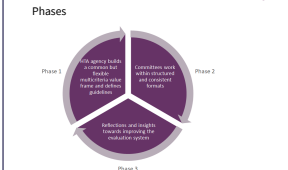
- TO ENABLE THE EVALUATION OF DISTINCT MEDICINES ON A COMMON BASIS
- TO BE ADAPTABLE AND FLEXIBLE
- TO BE THEORETICALLY SOUND
- TO IMPROVE DEMOCRATIC NATURE OF COMMITTEES AND CAPACITY KNOWLEDGE OF COMMITTEE MEMBERS
- TO PROMOTE STRUCTURED AND CONSISTENT EVALUATION PROCESSES

Objective: Building a common but flexible value framework to enable HTA agencies to evaluate new medicines on a common basis, and while considering the views of relevant stakeholders

IMPACT HTA Impact on health and technology Cost agreement No 77043



Phases



IMPACT HTA framework innovative features: model structure, combined MACBETH-Swing weighting matrix, embedded collaborative value modelling, actionable tools.

IMPACT HTA framework:

Socio-technical steps within the three phases


TECHNICAL

- Defining common set of value aspects to be considered in the evaluation of medicines and its associated structure, the value frame
- Defining guidelines for HTA committees
- Identifying relevant stakeholders and their views
- Identifying qualitative judgement knowledge for defining relevant and suitable MACBETH
- Model fitting, assessment and validation, making recommendations
- Testing the IMPACT HTA framework using two case studies: the evaluation, interpretation and feedback given by institution committees' members

SOCIAL

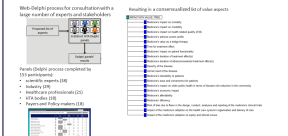
- Involving a larger number of agency stakeholders and experts through online, face-to-face and decision conferencing processes
- Making key group members evaluation guidelines
- Working collaboratively with a clear structured and transparent approach with the agency
- Using online Delphi and decision conferencing processes to build evaluation results
- Making key group of HTA agency stakeholders reflect on the available system and making decisions on the value frame

Two case-studies, for Non-Small Cell Lung Cancer (NSCLC); Spinal Muscular Atrophy (SMA) for HTA evaluation committees at the Swedish and Belgium national agencies



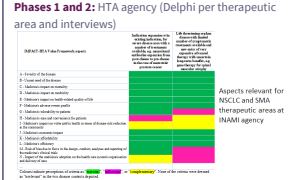
Phase 1: ex-ante to HTA agency (Delphi+Workshop)

Web-Delphi process for consultation on the design of a common value frame of value aspects



Phases 1 and 2: HTA agency (Delphi per therapeutic area and interviews)

IMPACT HTA Socio-Technical Framework

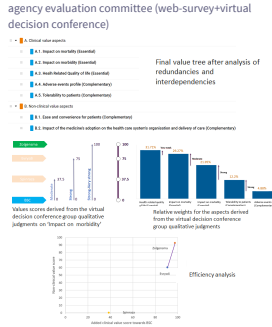


Aspects relevant for NSCLC and SMA therapeutic areas at INAMI agency

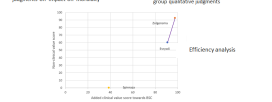
Phase 2: Spinal Muscular Atrophy case study with TLV agency evaluation committee (web-survey+virtual decision conference)

- Social value aspects
 - A1 Based on mortality (identified)
 - A2 Based on morbidity (identified)
 - A3 Non-quantifiable utility (identified)
 - A4 Above every other (Complementary)
 - A5 Transfers to others (Complementary)
- Involvement into equity
 - B1 Cost and convenience for patients (Complementary)
 - B2 Impact of the medication on the health care system (negative and positive of others (Complementary))


Final value tree after analysis of redundancies and interdependencies



Values on tree derived from the virtual decision conference group qualitative judgements on 'Impact on morbidity'



Efficiency analysis



Key results: 4 successfully developed case studies; framework flexible and effective in helping committees working aligned with the HTA agency value system.

Future research: Develop tools to enable an expedite implementation of the framework; consolidate the MACBETH swing weight matrix approach.

Figueira da Foz, 7 e 8 de novembro de 2021

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